# General Characterization of PCBs in South Lake Washington Sediments

DEPARTMENT OF ECOLOGY
State of Washington

King County

March 2010
Publication No. 10-03-014

## Publication and Contact Information

This report is available on the Department of Ecology's website at
www.ecy.wa.gov/biblio/1003014.html

Data for this project are available at Ecology's Environmental Information Management (EIM) website www.ecy.wa.gov/eim/index.htm. Search User Study ID, BERA0006.

Ecology's Study Tracker Code for this study is 09-254.

For more information contact:

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

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

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

Cover photo: Sediment grab taken from south Lake Washington.

# General Characterization of PCBs in South Lake Washington Sediments

by

Brandee Era-Miller

Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington 98504-7710

and

Richard Jack and Jenée Colton

King County Department of Natural Resources and Parks
Water and Land Resources Division
Seattle, Washington 98104

Waterbody Number: WA-08-9350

*This page is purposely left blank*

# Table of Contents

# List of Figures and Tables

Page

## Figures



## Tables

# Abstract

The Washington State Department of Ecology, in collaboration with the King County Department of Natural Resources and Parks, conducted a study to characterize the distribution of polychlorinated biphenyls (PCBs) in surface sediments of Lake Washington. PCBs are bioaccumulating in Lake Washington fishes to levels failing to meet (exceeding) human health standards, and PCBs in sediments could be a source to fish.

In spring of 2009, surface sediments (0-2 cm) were collected from 52 locations in the southern portion of Lake Washington (south of Interstate 90) and analyzed for PCBs. A single sediment core was also collected and analyzed for PCBs.

Total PCB concentrations in surface sediments ranged from 3.3 to 57 ug/Kg dry weight (dw). The sediment core followed the trend of PCB use over the past century, with concentrations peaking at 250 ug/Kg dw around 1971 then dropping swiftly after PCB use was banned.

To determine if the PCB concentrations measured in sediments from the current study could impact human health through consumption of contaminated fish, northern pikeminnow bioaccumulation was modeled using a food web model. The model predicted fish tissue concentrations with about 32% low bias, but still indicated that current surface sediment PCB concentrations are high enough to result in PCB concentrations in fish tissue potentially hazardous to human health. Model sensitivity testing revealed that sediments drive the majority of PCB bioaccumulation fish. Reductions in sediment appear to be key in reducing PCB concentrations in northern pikeminnow.

Further investigations of the ongoing, albeit low, sources of PCBs to surface sediment are warranted to quantify the PCB reductions necessary to ensure fish meet regulatory and human health standards.

#  Acknowledgements

The authors of this report would like to thank the following people for their contribution to this study:

- Peter Rude, Ingrid Wertz, and Jonathan Frodge, and others from the City of Seattle Public Utilities for providing valuable comments on the report.

Washington State Department of Ecology staff:

- Keith Seiders and Dale Norton for piloting the *R.V. Skookum* and helping with sediment collection.
- Janice Sloan for assisting with sediment collection and reviewing final data in Ecology's EIM database.
- Chad Furl and Callie Meredith for processing sediment core samples and determining horizon ages.
- Manchester Environmental Laboratory staff: Karin Feddersen, Myrna Mandjikov, Dean Momohara, Leon Weiks, Nancy Rosenbower, and others.
- Tom Gries and Dale Norton for providing peer review of the draft report.
- Joan LeTourneau and Cindy Cook for formatting and editing the final report.

# Introduction

In the spring of 2009, The Washington State Department of Ecology (Ecology), in collaboration with the King County Department of Natural Resources and Parks, initiated an investigation into possible sources of polychlorinated biphenyls (PCBs) bioaccumulating in Lake Washington fishes to levels not meeting human health standards. The investigation focused on sediments.

A number of important factors motivated Ecology to study PCB concentrations in surface sediments from Lake Washington. These factors include: (1) the current fish consumption advisory for PCBs, and (2) the absence of adequate sediment chemistry data to characterize the spatial distribution of PCBs in Lake Washington.

The study area was defined as the southern portion of the lake (south of the I-90 Bridge) because limited historical data indicated that the highest PCB concentrations were located in south Lake Washington. Researchers also wanted to collect samples at close enough intervals to notice any patterns in the distribution of PCBs in the nearshore environment. Limiting the study area to the southern portion of the lake allowed for such a focused sampling regime.

Ecology and the King County Department of Natural Resources and Parks (KCDNRP) developed and followed a sampling plan (Era-Miller, 2009) to characterize the spatial distribution of PCBs in recently deposited sediments. Characterizing PCB spatial distribution in surface sediments is the first step in determining whether active PCB sources are present and what type of source controls (point versus nonpoint) may be needed.

The results of this study will help Ecology better understand the sources of PCB contamination to the lake and the pathways by which PCBs bioaccumulate in fish tissue. In the long term, this information will help Ecology conduct further source tracking investigations and work with local communities and businesses to find management options to reduce the sources of PCBs to south Lake Washington.

## Site Description

Lake Washington is the largest of the three major lakes in King County and is the second largest natural lake in Washington State. It is located just east of Puget Sound and between the cities of Seattle and Bellevue (Figure 1). Lake Washington has two major tributaries: the Cedar River at the southern end, which contributes about 57% of the annual surface water flow, and the Sammamish River in the north, which contributes 27% of the surface water flow. The remainder of the water comes from small local drainages and groundwater. The majority of the immediate watershed is highly developed and urban in nature with 63% fully developed. The upper portion of the Cedar River watershed is part of the Seattle Water Department drinking water supply which is closed to public access (King County, 2009a).

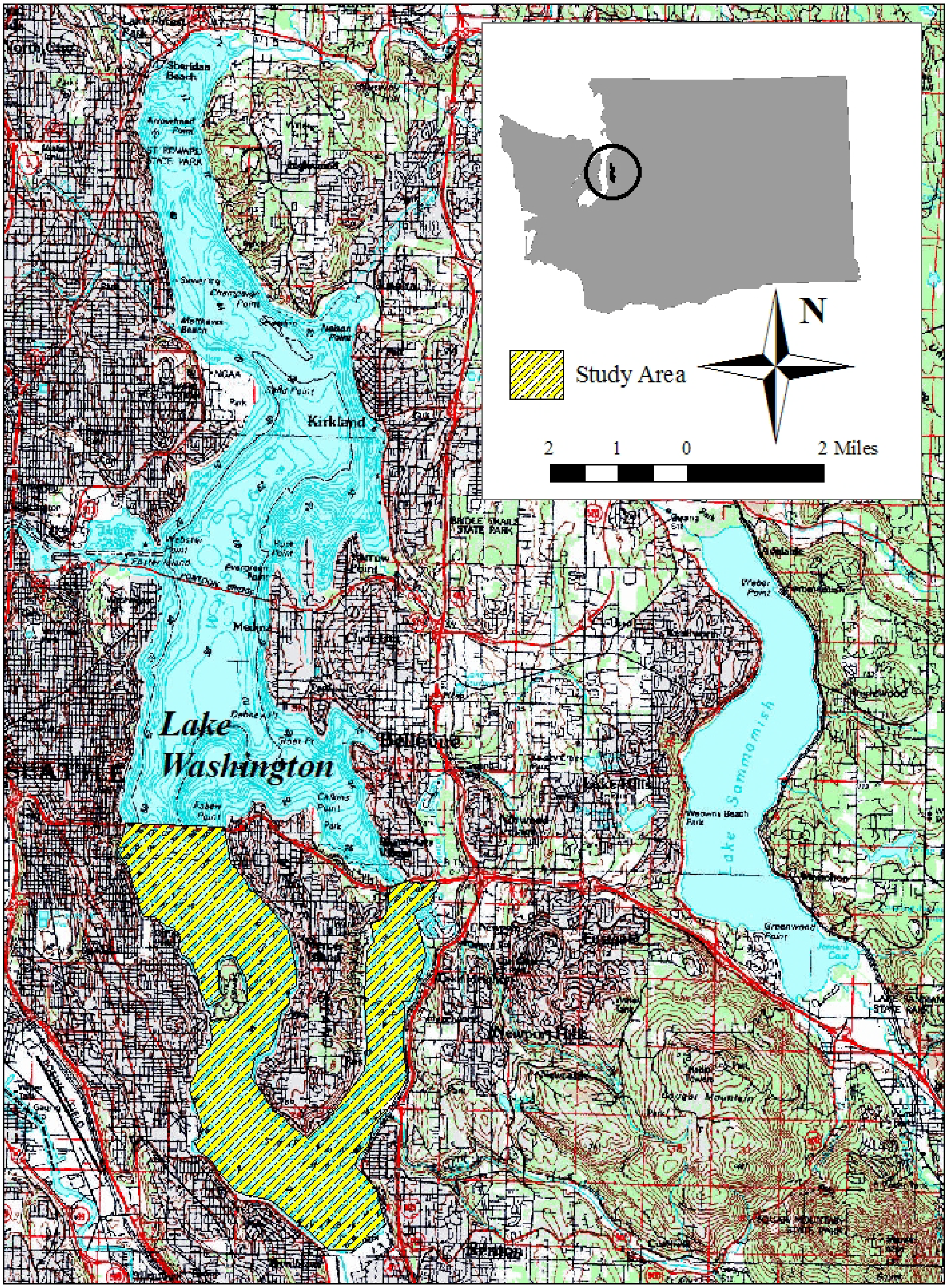


Figure 1. Lake Washington Study Area.

Lake Washington is a deep, narrow, glacial trough with steeply sloping sides, sculpted by the Vashon ice sheet, the last continental glacier to move through the Seattle area. The lake is 20.6 feet above mean lower low tide in Puget Sound. The Lake Washington Ship Canal was constructed in 1916, and is the only outlet from Lake Washington to Puget Sound via Lake Union and the Ballard Locks. Construction of the canal resulted in the lowering of the lake 9 feet to its present level, leaving the Black River dry and the Cedar River diverted into Lake Washington. Mercer Island lies in the southern half of the lake, separated from the east shore by a relatively shallow and narrow channel, and from the west shore by a much wider and deeper channel (King County, 2009a).

The lake received increasing amounts of treated sewage between 1941 and 1963, which resulted in eutrophication and impaired water quality of the lake. These discharges were located around the entire lakeshore. In south Lake Washington, discharges occurred in the Cedar River, near Bellevue, Skyway (southwestern shore), and from Boeing industrial waste.

Planktonic algae were dominated by blue-green bacteria (algae) from 1955 to 1973. Except for combined sewer overflows, all sewage discharges were diverted from the lake by 1968. Rapid and predicted water quality improvements followed; blue-green algae decreased and have been relatively insignificant since 1976 (King County, 2009a).

Land use around Lake Washington is currently high-density residential with limited industrial properties in specific locations. Most notable are the Boeing Plant and Renton Airport at the mouth of the Cedar River (south end of lake) and Kenmore Air and Kenmore Sand and Gravel Company at the mouth of the Sammamish River (north end of lake).

Historically, other industries were present such as Port Quendall Terminals, southeast of Mercer Island, and Puget Power and Light, next to the Boeing Plant. Some environmental investigations have been conducted near these facilities in the south end of Lake Washington. Port Quendall Terminals was listed on the Washington Model Toxics Control Act (MTCA) list in 1998 because of polycyclic aromatic hydrocarbon (PAH), arsenic, and volatile organic contamination. Cleanup oversight was transferred to the U.S. Environmental Protection Agency (EPA) in 2006, resulting in listing as a Superfund site. Currently, a remedial investigation is underway. The neighboring Barbee Mills site is on the MTCA list for arsenic, zinc, petroleum, hydrocarbons, and pentachlorophenol and is undergoing interim remediation actions (www.ecy.wa.gov/programs/tcp/sites/sites_information.html).

Environmental investigations from the l990s indicated that the Shuffleton Power Plant operated by Puget Power and Light (1929 -1989) and the Boeing Renton Plant may have been sources of PCBs to lake sediments. The data from these investigations are discussed in more detail in the following section of this report.

The researchers found no evidence that remediation actions are planned to address PCB contamination in Lake Washington sediments.

# Summary of Historical Data

## Fish

In the late 1990s, King County began a project to further understand hydrodynamics as well as nutrients and other contaminants in Lake Washington. As part of this project, King County funded a University of Washington master's thesis project during 2001–2003 that included fish tissue collection (McIntyre, 2004). Resident fish species were collected and analyzed for PCBs, mercury, and other contaminants. Based on the PCB levels, the Washington State Department of Health (DOH) issued an interim fish advisory for large and small mouth bass, yellow perch, cutthroat trout, and northern pikeminnow (DOH, 2004). DOH, in partnership with Ecology, collected more fish in 2005 to update the existing fish advisory for Lake Washington (DOH, unpublished data).

In 2005, Ecology monitored freshwater fish tissue in Washington and concluded that Lake Washington ranked second, out of 52 sites statewide, for having highly contaminated fish (Seiders et al., 2007). The highest concentrations of PCBs were measured in carp at a concentration of 1300 ug/Kg wet weight (ww). Ecology recommended follow-up action for the most contaminated sites, particularly Lake Washington, and the Wenatchee, Spokane, Snake, and Columbia Rivers.

All three datasets are shown in Table 1. For the 2005 DOH study, fish were collected and analyzed from the entire lake and from the northern and southern parts of the lake separately. Only fish from the southern part of the lake are included in Table 1 where sampling was conducted in separate portions of the lake.

Table 1. PCB Results for Lake Washington Fish, ug/Kg ww (parts per billion).

| Species | Size Class | Total PCBs* | Lipids (%) | Sample Size | Tissue |
|---|---|---|---|---|---|
| *2001-2003 King County/University of Washington Samples (DOH, 2004)* | | | | | |
| Smallmouth bass | all | 371 | N/A | mean of 3 individuals | whole |
| Cutthroat trout | S (<300 mm) | 79 | | mean of 10 individuals | |
| | L (>300 mm) | 377 | | | |
| Yellow perch | S (<200 mm) | 47 | | | |
| | M (201-271 mm) | 66 | | | |
| | L (>271 mm) | 191 | | mean of 9 individuals | |
| Northern Pikeminnow | S (<300 mm) | 140 | | mean of 10 individuals | |
| | L (>300 mm) | 1,071 | | | |
| *2005 Ecology Samples (Seiders et al., 2007)* | | | | | |
| Common carp | N/A | 1,339 | 10 | 1 composite (5 fish) | fillet |
| *2005 DOH Samples (unpublished data)* | | | | | |
| Yellow Perch (south lake) | N/A | 4.9 U | 0.6 | 1 composite (3 fish) | fillet |
| | | 18.9 J | 0.6 | | |
| | | 6.8 J | 0.6 | | |
| | | 4.8 U | 0.7 | | |
| Common Carp (entire lake) | | 201 | 1.4 | 1 composite (5 fish) | |
| | | 297 | 5.7 | | |
| | | 239 | 4.4 | | |
| | | 177 | 1.9 | | |
| Northern Pikeminnow (entire lake) | | 610 J | 3.4 | 1 composite (3 fish) | |
| | | 400 J | 5.2 | | |
| | | 116 | 2.7 | | |
| | | 920 J | 6.9 | | |
| | | 36 J | 2.2 | | |
| | | 42 | 2.6 | | |
| | | 94 J | 2.5 | | |
| Pumpkinseed (south lake) | | 9.5 J | 0.5 | | |
| | | 8.2 J | 0.5 | | |
| | | 6.9 J | 0.3 | | |
| Black Crappie (south lake) | | 5.8 J | 1.2 | | |
| | | 6.4 J | 0.6 | | |
| Cutthroat Trout (south lake) | | 600 J | 4.0 | 1 composite (5 fish) | |
| | | 320 J | 2.7 | | |
| | | 420 J | 3.7 | | |
| | | 44 | 2.5 | | |
| | | 33 J | 1.0 | | |
| | | 117 J | 3.7 | | |

*PCB concentrations are the sum of Aroclors 1254 and 1260.
N/A = not applicable.
U = the analyte was not detected at or above the reported sample quantitation limit.
J = the analyte was positively identified; the associated numerical value is the approximate concentration of the analyte.

## Sediments

Sediment chemistry data for PCBs in south Lake Washington are very limited. Existing information on PCBs in sediments comes from two sources: King County Department of Natural Resources and Parks (KCDNRP) and consultant reports submitted to The Boeing Company. All samples targeted the 0-10 cm depth, considered to be the biologically active zone (Ecology, 2003a).

KCDNRP collected a limited number of sediment samples in Lake Washington as part of its routine monitoring activities and special studies. The highest sediment concentrations were found in south Lake Washington. PCB Aroclor results for samples from south Lake Washington are available from years 1992, 1995, 1996, 2000 and 2007 (Figure 2). Total PCB concentrations range from 22 to 1,690 ug/kg dry weight (dw) with the highest concentrations in the east channel offshore of the Port Quendall property and the Seattle Seahawks headquarters. These locations are also near King County's East Force Main which collects sewage from Mercer Island and carries it under Lake Washington to the Renton Municipal Wastewater Treatment Plant, which eventually discharges to Puget Sound (King County, unpublished data).

Roy F. Weston, Inc. prepared two reports for The Boeing Company that present concentrated sampling offshore of the current Boeing Company's Renton Facility (Weston 1997, 1999). The earlier report characterizes sediment quality in nearshore sediments adjacent to Washington State Department of Natural Resources (DNR) property and the Boeing Renton Facility.

Historically, cooling water discharges from the Shuffleton Power Plant, operated by Puget Power & Light (1929-1989), entered Lake Washington via a flume. In 1966/1967, Lake Washington sediments were dredged and used to fill in the nearshore between the Inner and Outer Harbor Lines, thereby creating an uplands parcel owned by Washington State DNR. When this parcel was created, a new discharge flume was constructed and used for the remainder of the power plant's operating life. Ten samples were collected in the vicinity of this flume by Roy F. Weston in 1997 (Weston, 1997) (Figure 3). Total PCB concentrations ranged from 9 to 146[1] ug/kg dw. The highest concentrations were located near the mouth of the flume.

The 1999 report was produced in compliance with an Agreed Order between The Boeing Company and Ecology. This was intended to evaluate threats to human health and the environment from potential hazardous chemical releases by the Boeing Renton Facility (Weston 1999). A total of 37 samples were collected near 9 stormwater outfalls at the Boeing property and 2 non-Boeing discharge points (Figure 3). Total PCB concentrations ranged from 7 to 760 ug/kg dw. The highest concentration was located about 200 feet west of the flume mouth. However, the 3 next highest concentrations were located much further west, about 600 to 800 feet from the flume mouth and close to shore.

[1] Sediment PCB concentrations were reported as normalized to organic carbon in the 1997 Weston publication. Values reported here were back-calculated to dry weight basis.

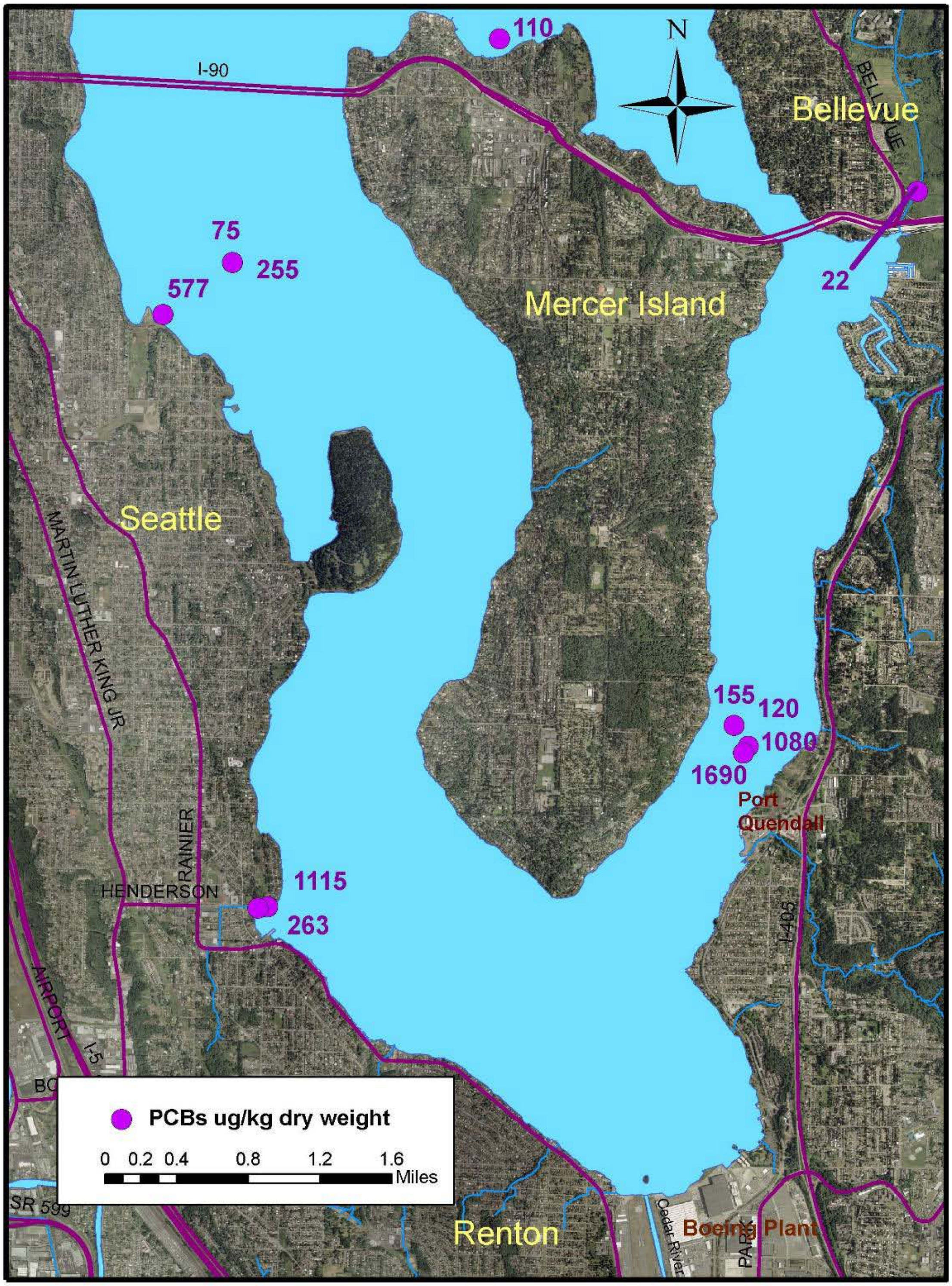


Figure 2. King County Data for Total PCBs in 0-10 cm Surface Sediments (1992 -2007).

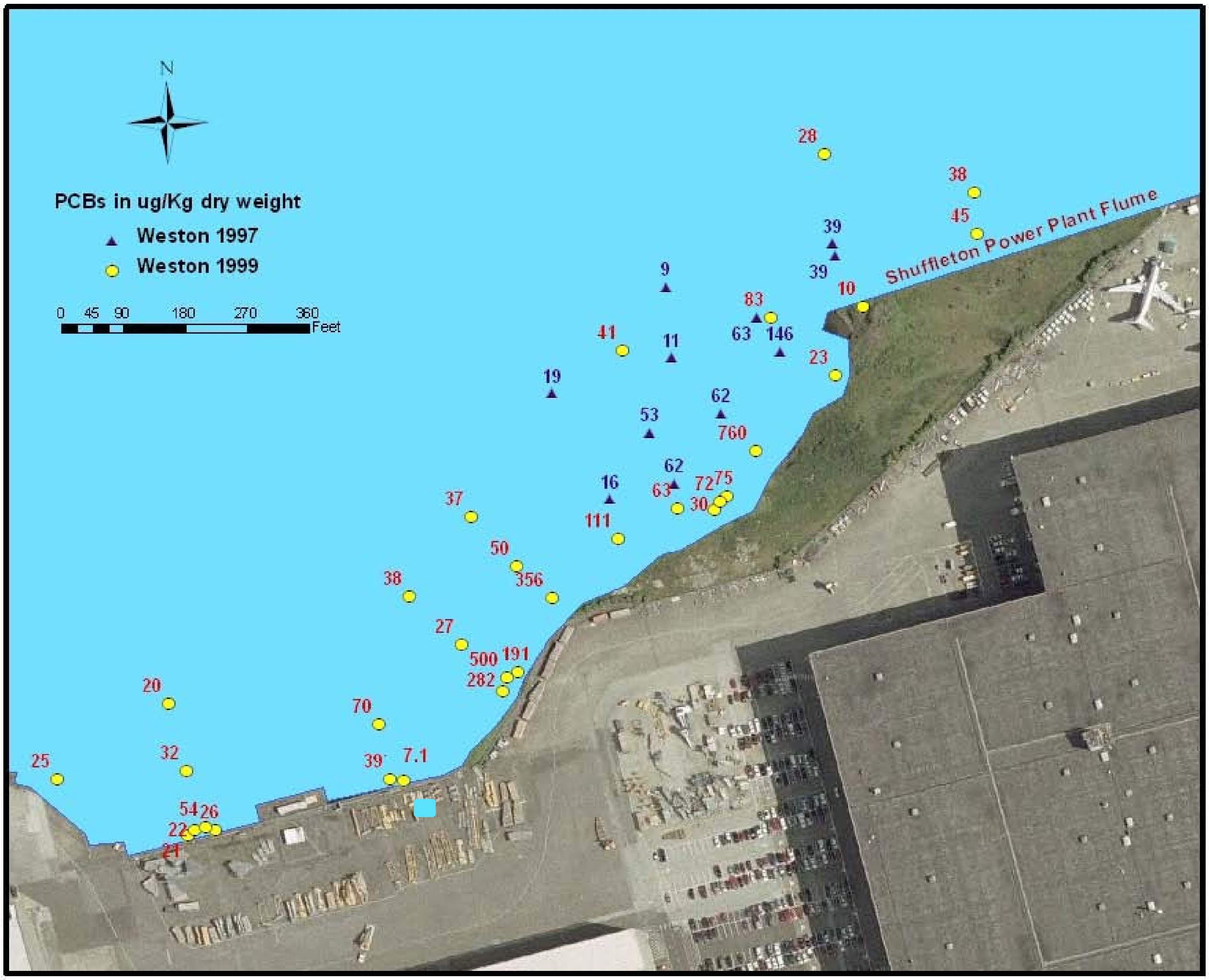


Figure 3. Historical Data for Total PCBs in 0-10 cm Surface Sediments Adjacent to the Boeing Renton Facility.

# Project Description

The primary objectives of the project were to:

1) Characterize the distribution of PCBs in surface sediments from recent and active sources.
2) Screen for areas of relatively high PCB concentrations in the nearshore environment of south Lake Washington.

For the purposes of the project, south Lake Washington refers to the lake area south of Interstate 90 (see Figure 1).

The study focused on south Lake Washington because historical data showed elevated concentrations of PCBs in the sediments from the southern portion of the lake. Focusing on one portion of the lake also gave researchers the ability to characterize PCB concentrations on a finer scale.

Sediment sampling in the 0-10 cm horizon is typical for purposes of determining benthic toxicity or remediation decisions because this is generally accepted as the biologically active zone. However, the 0-2 cm horizon was targeted to meet this study's objective of characterizing sediments deposited from active inputs to the Lake. Sampling of this more surficial sediment layer obtains a sample representing more recent deposition in a lake such as Lake Washington, where deposition rates are low (<1 cm a year).

Additional objectives for the study include:

- Evaluate PCB deposition trends in Lake Washington by analysis of an age-dated sediment core.
- Evaluate offshore gradients by analyzing PCB samples collected along three transects perpendicular to the shoreline, spanning shallow-to-deep water sections.
- Use a standard bioaccumulation model to determine the relative contributions of sediment and water to PCB bioaccumulation in fish.

*This page is purposely left blank*

# Methods

Ecology in conjunction with King County identified a total of 52 discrete locations to sample surface sediments in south Lake Washington. Figure 4 displays all the sampling locations (and their associated station identification numbers) for the 2009 study.

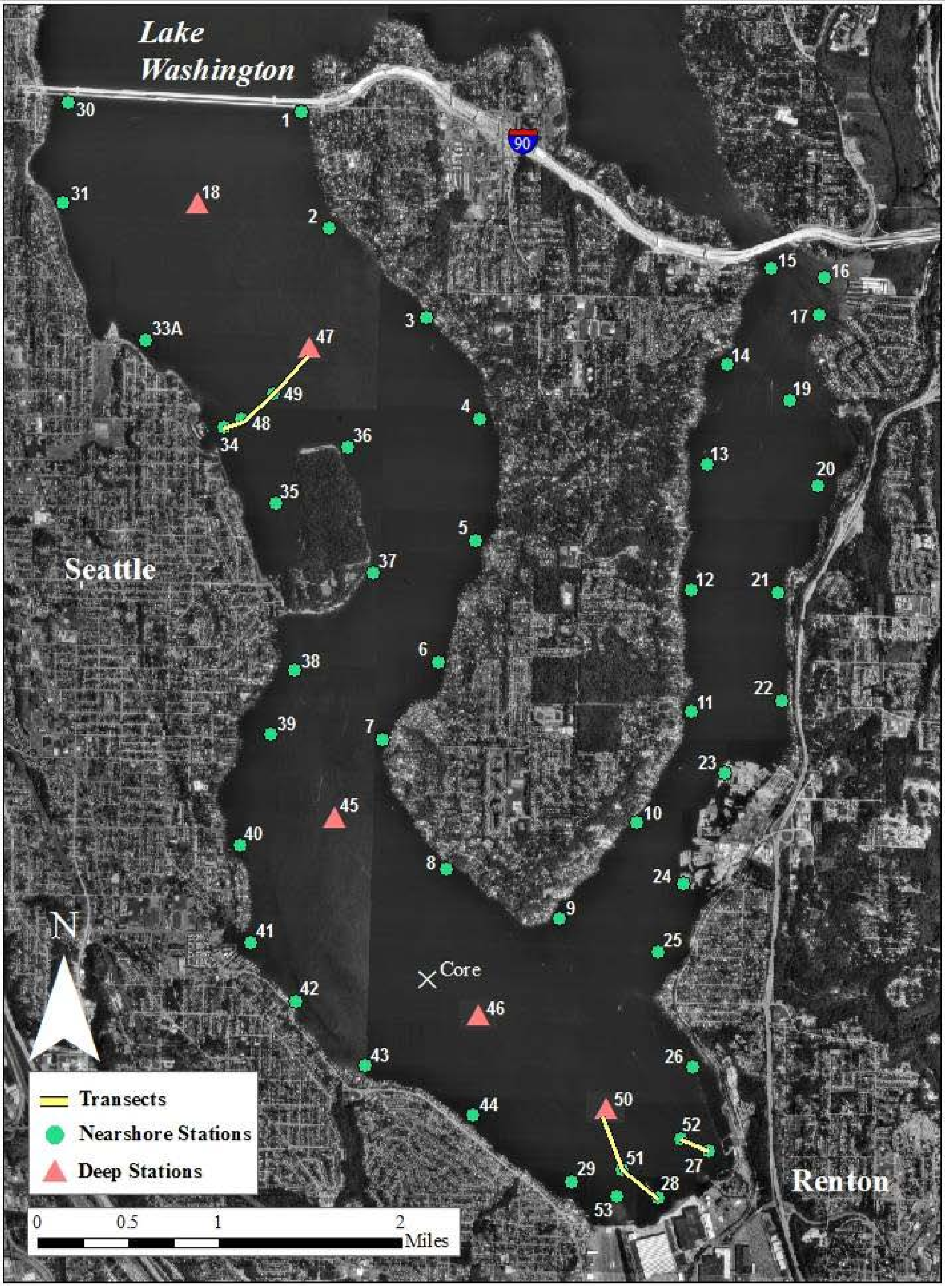


Figure 4. Sampling Locations (with station ID) for the South Lake Washington PCB Study.

Approximately 43 nearshore locations were sampled to identify areas with elevated concentrations of total PCBs that may indicate ongoing upland sources. Nearshore sampling locations were at approximately 0.5 to 1 mile intervals along the shoreline perimeter of south Lake Washington.

Water depths of 40 to 60 feet were targeted for the nearshore sampling locations. Locations were moved slightly in a different direction or depth from shore in cases where the targeted locations did not yield an acceptable sample (e.g., when a targeted location was too rocky or it was located over a buried cable or other obstruction). Depths of 40 to 60 feet were chosen to avoid the difficulty of sampling around milfoil and other aquatic plants. Milfoil typically does not grow at depths deeper than 40 feet in Lake Washington.

Five locations were sampled in deep water (greater than 60 ft). Three transects were sampled perpendicular from the shoreline out to deep water, using 4 additional samples to supplement some of the nearshore and deepwater locations. Two transects were located at the south end of the study area offshore of the Boeing Renton Facility and the Washington State DNR parcel, and a third was located north of Seward Park on the western shore of the lake.

In addition to the surface sediment sampling, a single deep sediment core was analyzed to help determine deposition trends for PCBs over time. The core station location was selected because it is mid-channel (i.e., equidistant from shoreline inputs) and at a depth that is average for the study area. The sediment core was collected in August 2008, in collaboration with another Ecology study: *Determination of PBT Chemical Trends in Selected Washington Lakes Using Age-Dated Sediment Cores* (Furl et al., 2009).

## Surface Sediments

Surface sediments were collected in February and March 2009 in south Lake Washington using Ecology's 26-foot research vessel, the RV Skookum. Sampling methods followed Ecology's Standard Operating Procedure (SOP) for obtaining freshwater sediment samples (Blakley, 2008). Sediments were taken with a Van Veen grab sampler.

Surface sediment samples were composites of 3 grabs from each site. Differentially corrected GPS coordinates were collected for each grab. Every attempt was made to keep the vessel within a 10-meter circle of the targeted site for each grab in the composite sample. Location information and sediment quality descriptions are shown in Appendix B, Table B-1. The centroid positions of the 3-grab clusters were entered into Ecology's Environmental Information Management (EIM) database.

Overlying water was siphoned off prior to sub-sampling. Approximately equal volumes of the top 2-cm of sediment were removed from each of the 3 separate grabs per composite. Stainless steel spoons and bowls were used for sub-sampling and to homogenize sediments from each station to a uniform consistency and color. Sediments contacting the sides of the grab sampler, and large pieces of debris such as rocks, sticks, and leaves, were not retained for analysis.

All equipment used to collect surface sediments was cleaned using the procedure described in the *Decontamination Procedures* section of this report. To avoid cross-contamination between sample sites, the grab sampler was thoroughly brushed down with on-site water and diluted Liqui-Nox® detergent prior to the next sample location.

Surface sediment samples were placed in coolers on ice immediately following collection, then transported to Ecology's Manchester Environmental Laboratory. Surface sediments were analyzed for PCB Aroclors, total organic carbon (TOC), total solids, and grain size. Chain-of-custody was maintained throughout the sampling and analysis process.

## Sediment Core

A single deep sediment core was collected in August 2008. Sampling methods followed Ecology's SOP for collection of freshwater sediment core samples (Furl and Meredith, 2008). The core was taken using a Wildco stainless steel box corer fitted with a 13 cm x 13 cm x 50 cm acrylic liner. The core reached approximately 37 cm and looked well intact. Thirty-seven cm was the deepest core depth Ecology could achieve in the sampling area. This depth was deemed adequate based on previous Ecology studies, where adequate depths ranged from 25 to 45 cm (Norton, 2004; Coots and Era-Miller, 2005).

After retrieving the core, overlying water was carefully siphoned off and the acrylic liner removed from the corer. The sediment-filled liner was placed on an extruder table outfitted with a gear-driven piston to push sediments up and out of the liner. Sediment horizons were sliced with thin aluminum plates to a uniform thickness of 1 cm. Each sample layer was transferred to an 8-oz glass jar, placed in plastic bags on ice, and stored in coolers on ice. The samples were then transferred to freezers at Ecology and later processed for analysis.

Sediment horizons selected for analysis were homogenized prior to dividing for analysis. Homogenized sediments were split into sub-samples for analysis of PCB congeners, TOC, total lead, and lead$^{210}$ for dating.

## Decontamination Procedures

Decontamination procedures are described in depth in both the SOP for surface sediment collection and the SOP for sediment cores (Blakley, 2008; Furl and Meredith, 2008). Precautions were taken to minimize contamination during both sample collection and sample processing. Persons collecting and preparing samples wore non-talc nitrile gloves.

Utensils used in collecting and manipulating sediment samples were washed thoroughly with tap water and Liqui-Nox® detergent, followed by sequential rinses of hot tap water, de-ionized water, acetone, and hexane. Equipment was then air dried and wrapped in aluminum foil until used in the field. The same cleaning procedure was used on both the grab sampler and box corer prior to going into the field.

## Laboratory Analysis

The laboratory analyses used for this study are shown in Table 2. The lead$^{210}$, total lead, and TOC analysis for the core samples were completed through Ecology's PBT Chemical Trends Study (Furl et al., 2009).

Table 2. Laboratory Analytical Methods.

| Analysis | Analytical Method | Laboratory |
|---|---|---|
| *Surface Sediments* | | |
| PCB Aroclors | EPA 8082 | MEL |
| TOC | PSEP, 1986 | MEL |
| Grain Size | PSEP, 1986 | CAS |
| *Core Sediments* | | |
| PCB Congeners | EPA 1668A | Test America |
| TOC | PSEP, 1986 | MEL |
| Total Lead | EPA 200.8 | MEL |
| Lead$^{210}$ | EPA 901.1 | Test America |

MEL = Manchester Environmental Laboratory.
CAS = Columbia Analytical Services, Inc.

PCB congeners were chosen for the sediment core because low levels of PCBs were anticipated for the older/deeper horizons of the core. These horizons were expected to reach background (pre-PCB use) levels, and the PCB congener method can detect PCBs at much lower levels than the PCB Aroclor method. PCB Aroclors were analyzed in surface sediments because (1) of the anticipation of PCB levels being above detection limits and (2) PCB Aroclor analysis is more affordable which allowed for many more samples to be analyzed.

## Calculating Total PCBs

Total values for PCB Aroclors and congeners were summed using only detected results. In cases where no PCBs were detected in the sample, the highest detection limit of either Aroclor 1254 or 1260 was used as the total result value and qualified with a U or UJ. The detection limit for all the non-detected PCB congeners was 2 ug/Kg, dw. This value was used as the total PCB congener value for samples having no detections.

## Data Quality

Every effort was made to meet the data quality objectives outlined for the study in the Quality Assurance (QA) Project Plan (Era-Miller, 2009). Study results met most of the study measurement quality objectives (MQOs) shown in Table 3.

Table 3. Analytical Measurement Quality Objectives.[1]

| Parameter | Laboratory Control Samples | Laboratory Duplicates | Matrix Spikes | Matrix Spike Duplicates | Surrogate Standards | Lowest Concentration of Interest |
|---|---|---|---|---|---|---|
| | % recovery limits | RPD (%) | % recovery limits | RPD (%) | % recovery limits | |
| PCB Aroclors | 50-150 | ≤ 50 | N/A | N/A | 50-150 | 5 *u*g/Kg dry |
| PCB Congeners | 50-150 | ≤ 50 | N/A | N/A | 50-150 | 2 *u*g/Kg dry |
| TOC | 80-120 | ≤ 20 | N/A | N/A | N/A | 1% |
| Grain Size | N/A | ≤ 15 | N/A | N/A | N/A | 0.1% |
| Total Lead | 85-115 | ≤ 20 | 75-125 | ≤ 20 | N/A | 2 mg/Kg dry |
| Lead[210] | N/A | ≤ 25 | N/A | N/A | N/A | 1 dpm*/g |

[1]Quality Control (QC) limits from personal communication with MEL.
RPD = Relative Percent Difference.
N/A = not applicable.
dpm = disintegrations per minute.

All of the study data were carefully reviewed by Manchester Environmental Laboratory (MEL) and the project manager, and the data are useable as qualified by MEL. An overview of data quality for the study is discussed below for each chemical parameter; the corresponding tables are located in Appendix C. Laboratory case narratives can be found in Appendix F.

Results for total lead, lead[210], and TOC from the sediment core met MQOs. Data quality for these parameters is discussed in further detail in Furl et al. (2009).

## PCB Aroclors

MEL qualified many of the PCB Aroclor samples as estimates with a "J" for detected chemicals and a "UJ" for non-detects. This was mainly due to interference on the analytical instrument (see case narratives in Appendix D for more information). This is a common occurrence when chemical detections are low and generally close to detection limits. Only 35% of the detected PCB Aroclor total results were qualified with "J".

No Aroclors were detected in the method blanks. Laboratory control sample (LCS) and matrix spike recoveries met MQOs for all samples. Surrogate standards met MQOs with the exception of 2 samples, which recovered low and were therefore qualified as estimates ("J").

Analytical precision was measured as the relative percent difference (RPD) between laboratory duplicates and between matrix spike duplicates. Tables C-1 shows that the RPD for 1 of the 3 sets of laboratory duplicates was just above the MQO of 50%. The results for this duplicate pair were qualified as estimates (“J”). Analytical precision for the matrix spikes was very good (Table C-2).

Three samples were split in the field after being homogenized and were then submitted to the laboratory blind as field replicates. Measuring the RPD between field replicates gives an overall indication of analytical precision, natural variability native to the sample, and how well samples were processed in the field. As shown in Table C-3, field replicates results (split samples) for PCB Aroclors fell within RPD limits.

## PCB Congeners

No PCB congeners were detected in method blanks. LCS recoveries for the target analytes met study MQOs. Surrogate standards recovered well with the exception of one result (PCB-194), which was qualified as an estimate (“J”).

A laboratory duplicate was performed on 1 sample (Table C-4). A RPD could not be calculated since one of the duplicate samples had no detections. The laboratory duplicates were actually quite close for the individual detected congeners (within a factor of 3 of the detection limit of 2 ug/Kg dw).

Due to the high cost of analysis and limited amount of sample material, no field replicates (split samples) were analyzed for PCB congeners.

## Total Organic Carbon

TOC was not detected in any of the method blanks. LCS recoveries met study MQOs.

Three samples were analyzed as laboratory triplicates. RPDs for TOC ranged from 5-19%, meeting study MQOs. Because MEL analyzed the TOC samples as triplicate samples, precision was measured as relative standard deviation (RSD) in Table C-5. RSD is a better measure of precision when there are more than 2 numbers being compared.

Field replicate results (split samples) for TOC fell within RPD limits (Table C-3).

## Sediment Grain Size

Three samples were analyzed as laboratory triplicates. Table C-6 gives the RSD values for grain size. RSDs for the individual grain size measurements (gravel, sand, silt, and clay) ranged from 0-18%, but the average RSD values for the samples were better at 6-11%. Average RPDs ranged from 8-19%, very close to the study MQO of 15%.

Field replicate results (split samples) for grain size fell within RPD limits (Table C-3).

# Results

## Surface Sediments

Surface sediments from 52 locations were analyzed for 9 PCB Aroclors, grain size, TOC, and solids. All results are shown in Appendix B, Table B-2. PCBs were detected in over 75% of the samples. Aroclors 1254 and 1260 were the most frequently detected Aroclors. Aroclor 1254 was detected in 60% of samples, and Aroclor 1260 was detected in 35% of the samples. The only other detected Aroclors were 1016 and 1248 with only 1 detection each.

Total PCB concentrations (expressed as the sum of detected Aroclors) were low overall, ranging from 3.3 to 57 ug/Kg dw. Figure 5 shows the relative concentrations of total PCBs in the south Lake Washington study area. The PCB concentrations were generally homogenous across the study area with some spatial patterns evident. The highest concentrations were along the southwestern shoreline, and the lowest concentrations were along the western shoreline of Mercer Island and at the mouths of the Cedar River and Mercer Slough. Variability in PCB concentrations was low and within a factor of 10.

Results for solids, TOC, and grain size are also shown in Appendix B, Table B-2. Solids results ranged from 13 – 68%, and TOC results ranged from 0.4 – 9.7%. Figure 6 presents the TOC data in a box and whisker plot. Grain size results are displayed in Figure 7. Results were comprised mainly of sand and silt with lesser amounts of gravel and clay**.** Fines (silt + clay fractions) ranged from 7 – 91%.

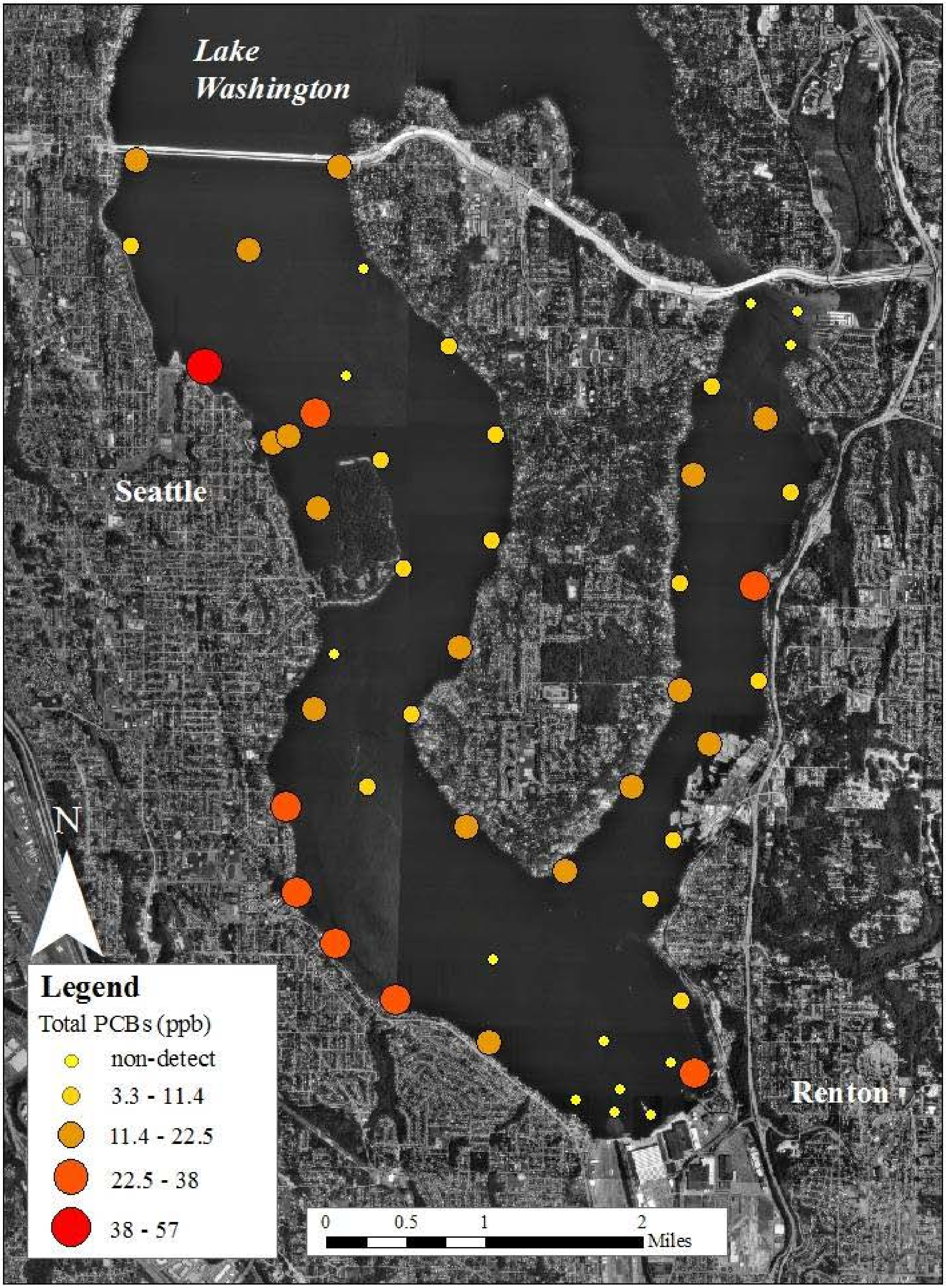


Figure 5. Total PCB Concentrations in 0-2 cm Surface Sediments of South Lake Washington (ug/Kg or ppb dry weight).

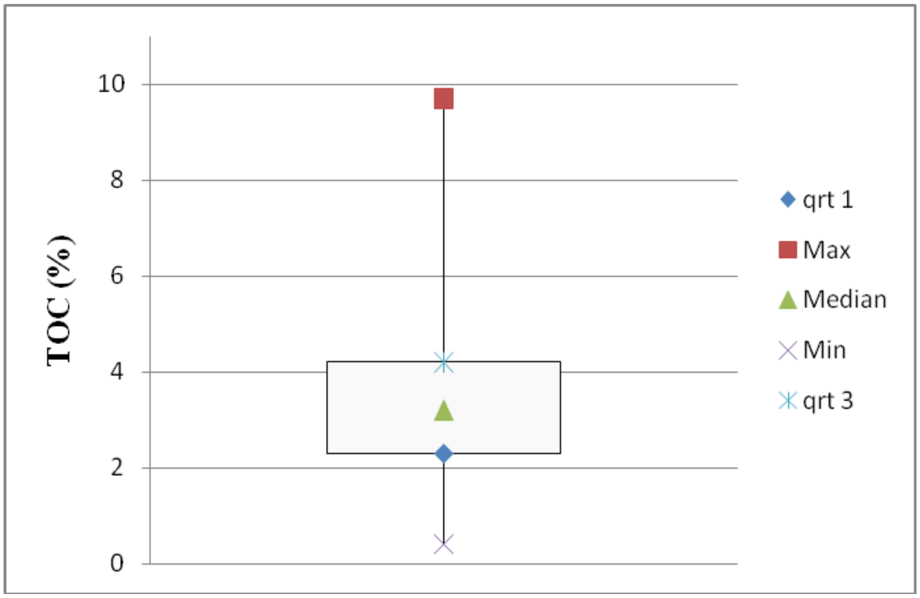


Figure 6. Box and Whisker Plot of TOC Surface Sediment Data.

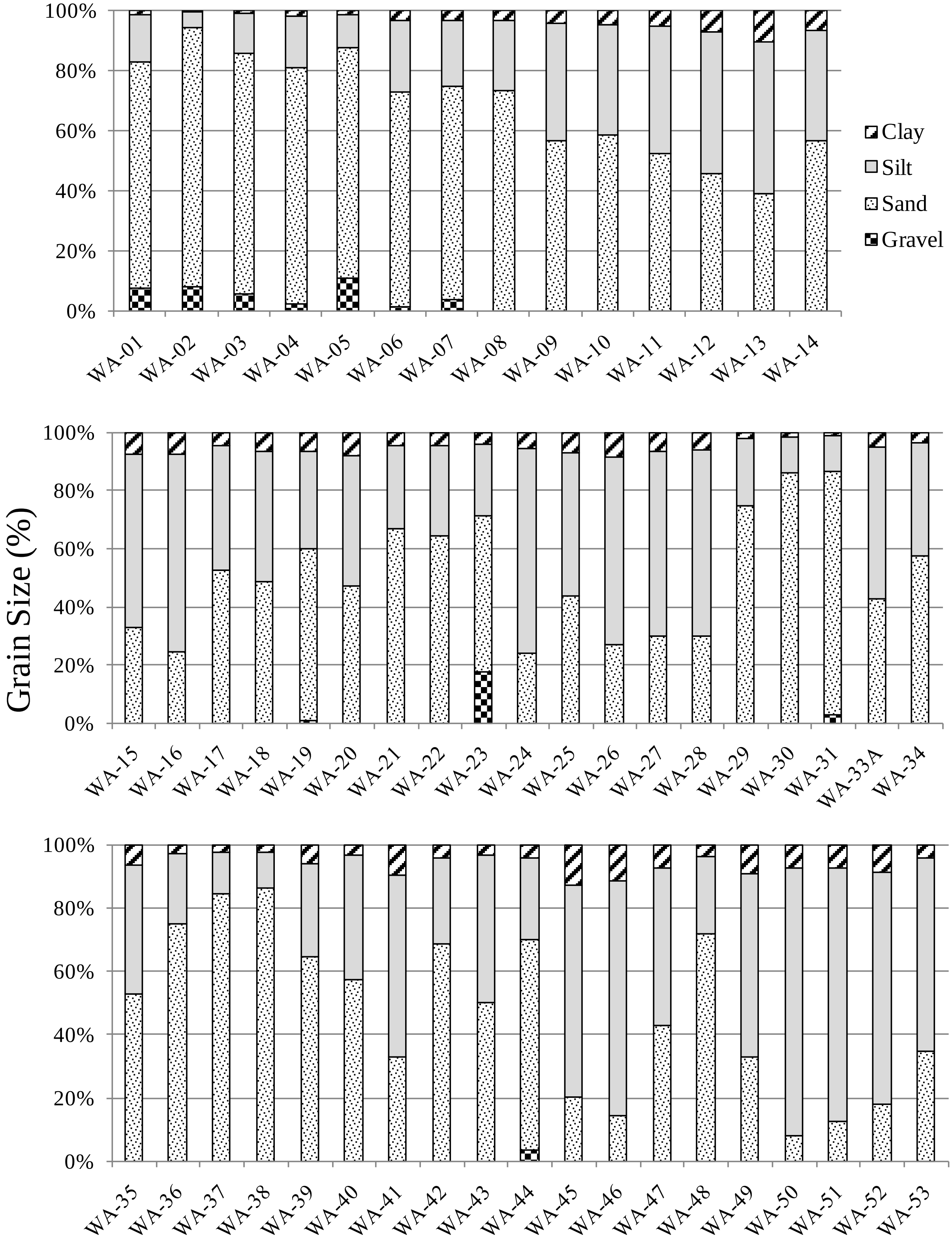


Figure 7. Grain Size Distribution of Lake Washington Surface Sediments.

## Sediment Core

The age of the sediments in the horizons (layers) of the core were determined using the constant rate of supply (CRS) model and analysis of $lead^{210}$ and stable lead. The process for estimating age in the sediment core is described in further detail in Furl et al. (2009). Results for $lead^{210}$ and additional chemistry can also be found in Furl et al. (2009) (Ecology EIM Study ID CFUR0004).

Results for the south Lake Washington sediment core are shown in Figure 8 and tabulated in Appendix B, Table B-3. Results are expressed as total PCB congeners in ug/Kg dw. PCBs were not detected prior to 1941, began to rise in the 1950s, peaked around 1971, and then dropped swiftly and began to level out by the early 1980s.

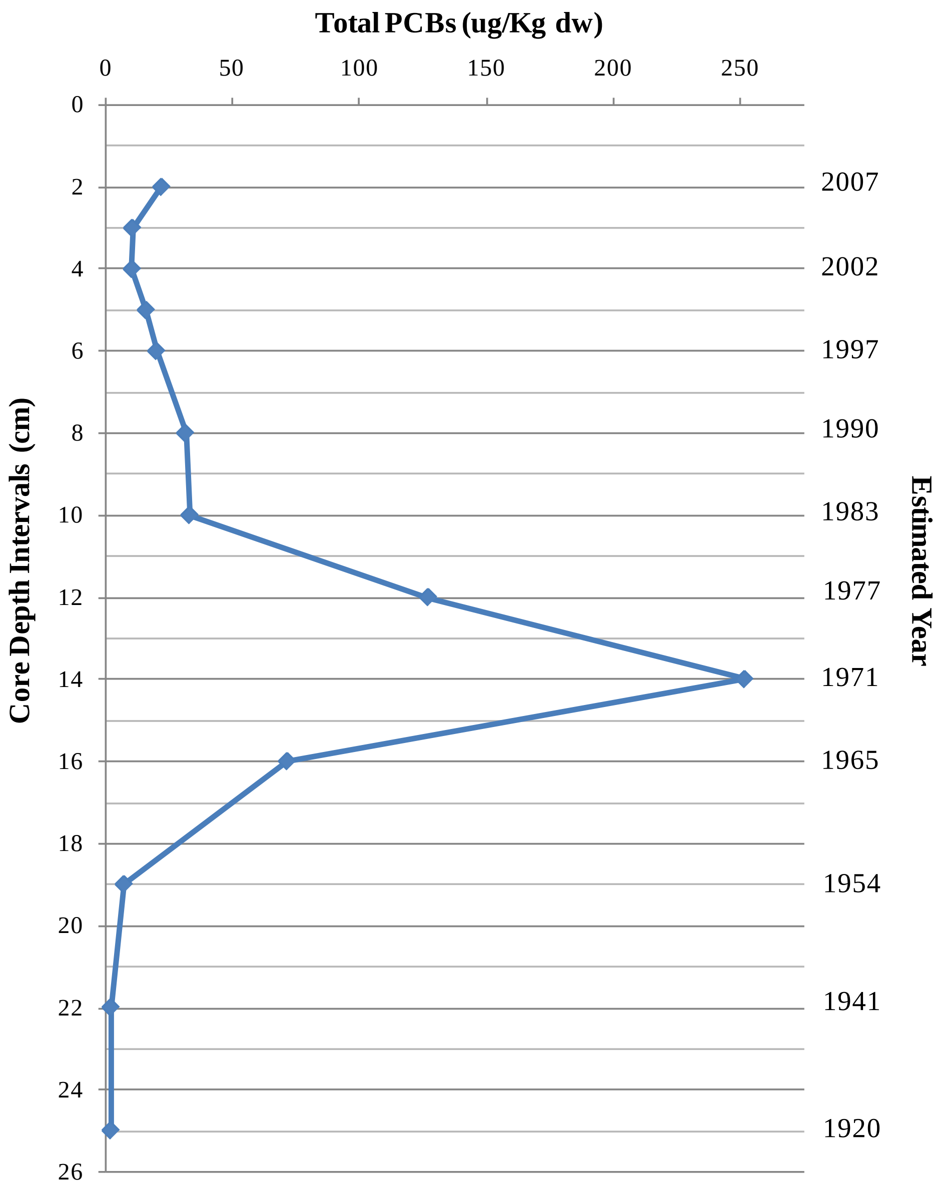


Figure 8. PCB Concentrations in a 2008 Sediment Core from South Lake Washington.

Although it appears that PCBs are increasing in the most recent horizon (0-2 cm), it is difficult to know if it is a real trend. The sample for this horizon was split and analyzed separately in the laboratory. One result had no PCB congener detections at a detection limit of 2 ug/Kg dw. The other result had several detections, all very close to the detection limit. The summed total PCB result for the duplicate sample with detected congeners was 28 ug/Kg dw. The actual concentration for this sample is somewhere between 2 and 28 ug/Kg dw, very close to the results in the 4 preceding horizons. Station 46, the closest deep surface station to the core, showed no detections of PCB Aroclors in surface sediments.

# Discussion

## Surface Sediments

### Lake Washington PCBs Compared to Other Washington State Lakes

Lake Washington sediments were compared to the sediments of 2 other Washington State lakes (Coots, 2007; Coots and Era-Miller, 2005). All 3 studies were conducted by Ecology and sampled the 0-2 cm layer and analyzed for PCB Aroclors using the same analytical methods. All three lakes are listed on the federal Clean Water Act Section 303(d) List of Impaired Waters for PCBs in fish tissue.

Figure 9 shows the mean total PCB concentrations for the lakes. Total PCBs were calculated the same way as described in the *Methods* section of this report. Non-detected results for total PCBs were included in the mean calculations for all 3 studies. Lake Washington PCB concentrations were 2-3 times higher than those in Lake Chelan and Lake Vancouver.

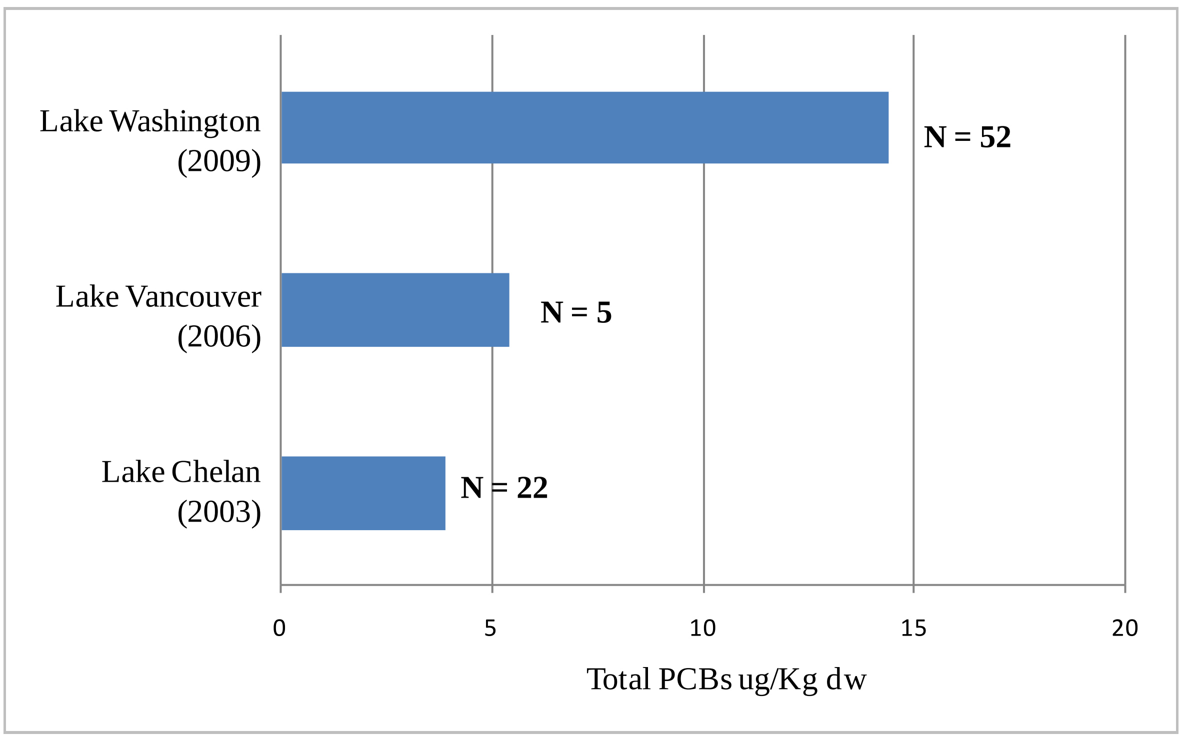


Figure 9. Mean PCB Values in the Surface Sediments of Three Washington State Lakes.

## Spatial Distribution of PCBs

As mentioned earlier in the report, PCB concentrations in 0-2 cm surface sediments were generally similar across the study area. The highest concentrations were found along the southwestern shoreline. The lowest concentrations were along the western shoreline of Mercer Island and at the mouths of the Cedar River and Mercer Slough. PCBs were not detected at the mouths of the Cedar River and Mercer Slough. This is likely due to dilution by "cleaner" riverine sediments depositing onto the deltas and covering historical sediments with higher PCB concentrations; a pattern also seen in the sediment core. Residual concentrations in the top 2 cm are a product of bioturbation from deeper sediments, new sediment deposition, and atmospheric deposition. Distinguishing these 3 influences is not possible with the current dataset.

Several transects, perpendicular to the shoreline, spanning shallow to deep water sections were analyzed for PCBs (see Figure 4). No patterns were discernable from these transects except that the deeper mid-lake sites were generally lower in PCBs. This suggests that local shoreline inputs are a more important determinant of the 0-2 cm PCB concentration than atmospheric deposition which is presumably more evenly distributed at the scale of a few hundred meters (the distances between sampling locations). Demonstrating the relative magnitude of shoreline inputs versus atmospheric deposition would require more data on shoreline sources and atmospheric deposition.

Three statistical tests showed that PCBs correlated well with both TOC and fines (silt + clay fractions). Statistical tests included the Pearson, Kendall's tau, and Spearman's rho and are shown in Appendix D, Tables D-1 through D-4. Only detected PCB results were used (n=42) to avoid spurious correlations solely due to detection limits. These correlations are not surprising as organic contaminants such as PCB Aroclors are known to preferentially partition to organic carbon, which is reflected in their high octanol-water partitioning coefficient ($K_{ow}$). TOC is also often higher in finer lake sediments because organic carbon is attracted to the charge of smaller mineral particles.

### Potential Effects of Drainage System Types on PCB Concentrations

Several geographic information systems (GIS) layers were examined for the potential to allow correlational analysis with sediment PCB concentrations and land use. The scale of land use categories was found to be too large to allow such an analysis. However, a trend visible in the spatial distribution of the sediment results is the more elevated concentrations on the western side of the study area. One possible difference between lake shore discharges is related to combined sewer (CS) areas and separated sewer (SS) areas.

In the early part of the 20$^{th}$ century, it was considered most efficient to build CS systems. A CS system is a network of drainage pipes that conveys both sewage and stormwater runoff to outfalls (Brown and Caldwell, 1958). CS pipes were eventually routed to Puget Sound, where feasible, and to pump stations and wastewater treatment plants along portions of Lake Washington.

The entire western shore of Lake Washington from the I-90 Bridge southwards to the Seattle city limits with unincorporated King County at Skyway (approximately S. 112th St.) is predominantly served by a CS network. In the 1960s and 1970s, this network was partially separated so that road runoff, which was assumed to constitute about 70% of the stormwater volume, discharges directly to Lake Washington via a stormwater-only drainage system. The remaining 30% of the stormwater volume remains in the combined drainage system, and along with sanitary effluent, is routed to pump stations and eventually to the West Point Wastewater Treatment Plant (City of Seattle, 2001).

During wet weather, this combination of sewage and roof runoff has the potential to overflow the finite pipe capacity. These overflows may discharge from various points along the conveyance system including 17 possible city overflow pipes in the south end of Lake Washington (City of Seattle, 2001) or at the two King County pump stations when their capacity is exceeded (King County, 2010). More recent modeling (Wertz, pers. comm.) suggests that CSO volumes are even smaller compared to stormwater volumes; as low as 1% CSO with 99% of the runoff to Lake Washington in this area coming from the partially separated stormwater-only system.

The remainder of the south Lake Washington shoreline is served by SS systems. This includes the cities of Mercer Island, Renton, Newcastle, and Bellevue. SS systems have distinctly different attributes than CS systems. The consequence of SS systems is that no sewage is discharged to Lake Washington during rain events as a combined effluent. These systems do not send dry-weather and low-flow rainfall events to the wastewater treatment plant. Instead nearly all stormwater runoff is discharged to Lake Washington.

Thus, these 2 different conveyance systems (CS and SS) differ in their potential to contribute contaminants to Lake Washington.

Figure 10 illustrates that PCB totals are highest along sections of shoreline with combined sewer pump stations. Whether this is coincidental, a consequence of the industries in these subbasins, or a function of the overflow frequency at these locations relative to other basins is unknown. Pump stations are often located near the mouths of streams, as these are natural topographic low points, and this further complicates understanding the influences on PCB concentrations.

Future investigations of PCBs should explore differences between CS and SS stormwater runoff along with the specific PCB and organic carbon characteristics of pump station overflows.

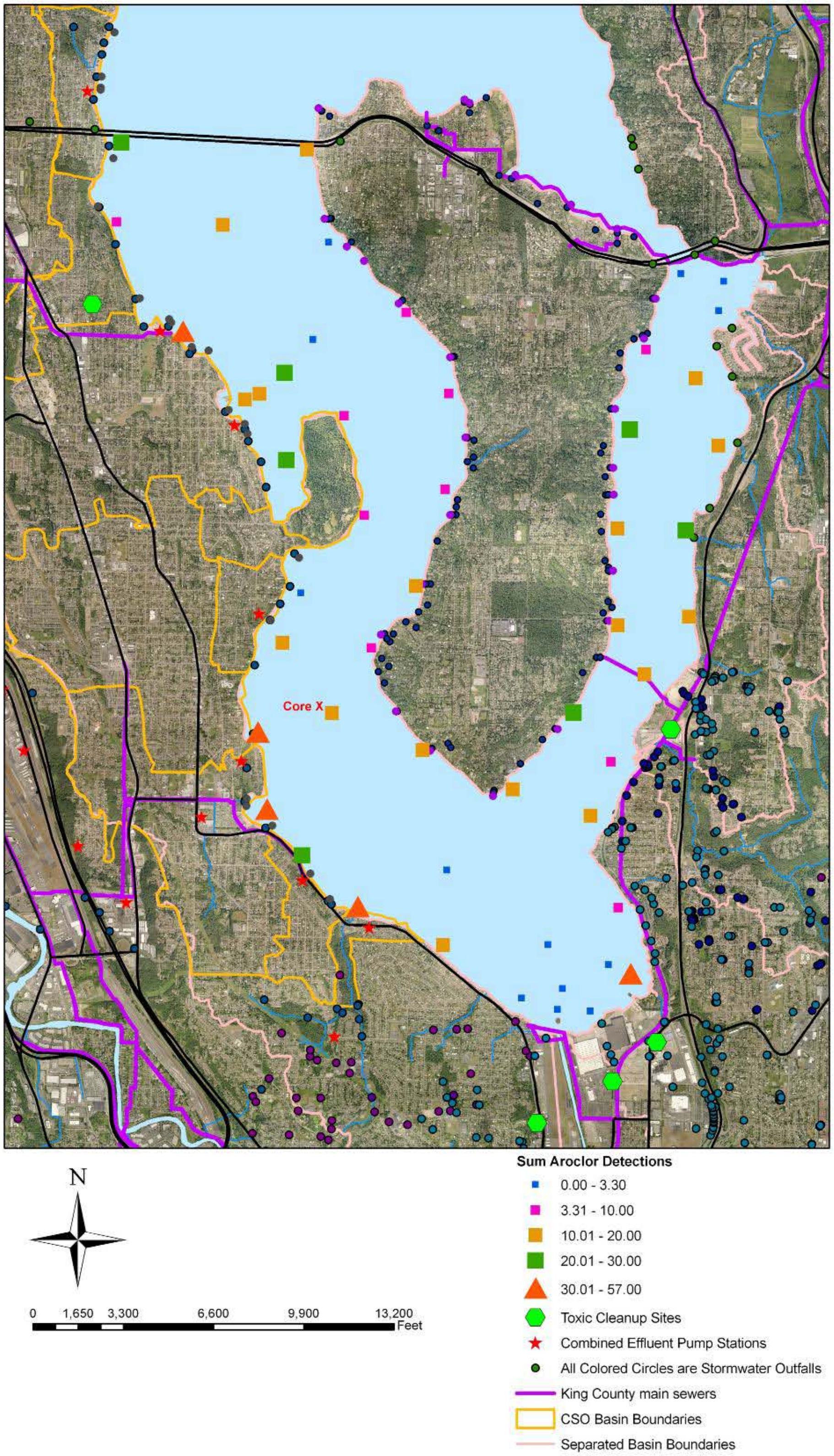


Figure 10. Total PCB Aroclor Detections Showing Pump Stations and Subbasin Boundaries.

## Bioaccumulation of PCBs in Fish Tissue

Washington State has not developed human health criteria for total PCBs in water and for fish consumption. Instead, the state uses the National Toxics Rule (NTR) criteria developed by EPA (40 CFR Part 131). The NTR criterion for total PCBs for water and fish consumption is 0.17 ng/L. A tissue concentration of 5.3 ug/kg ww total PCBs can be derived from the water criterion using bioconcentration factors.

There are no available sediment quality threshold criteria that incorporate risk from bioaccumulation for Washington's fresh waters. In order to determine if the PCB concentrations measured in sediments from the current study are high enough to potentially impact human health from fish consumption, northern pikeminnow (*Ptychocheilus oregonensis*) bioaccumulation was modeled using the food web model of Arnot and Gobas (2004). This model is called AQUAWEB v. 1.2. More information on the food web model can be found in Appendix E.

Comparison of modeled to observed fish tissue concentrations demonstrates that the model performs well (see Appendix E Figure E-1). Modeled concentrations within a factor of 2 compared to observed concentrations are typical and generally considered good performance for this model (Gobas, 1993; Morrison et al., 1997; Morrison et al., 1999). The modeled mean PCB concentration in northern pikeminnow is 730 ug/kg ww, more than 100 times the protective NTR fish tissue concentration of 5.3 ug/Kg. It can therefore be concluded that current surface sediment PCB concentrations are still high enough to result in northern pikeminnow tissue PCB concentrations, and presumably those of other fish species, potentially hazardous to human health.

The low bias of the predicted PCB concentrations may be due to uncertainties in model assumptions, higher concentrations not measured in the 2-10 cm biologically active zone, or to actual reductions in fish bioaccumulation since tissue PCB concentrations were last sampled.

Testing the sensitivity of the model to changes in sediment PCB concentrations indicates that the bioaccumulation of PCBs in northern pikeminnow is driven mainly by sediment contamination, but water PCB contamination may also play an important role. Reducing the sediment PCB concentration to zero and keeping the water concentration at 0.037 ng/L[2] in the model results in a northern pikeminnow tissue PCB concentration of 21 ug/kg. This is above the NTR; however, there is significant uncertainty associated with the water-only estimate.

Available measurements of total PCBs in water in or near Lake Washington are limited. Two samples were collected by semi-permeable membrane device (SPMD): one located in Lake Washington at Webster's Point, and one at the Montlake Cut (Sandvik, 2009). The method used to back-calculate total PCBs in whole water from the SPMD results also has unknown error because partitioning was modeled using a coefficient for total PCBs instead of congeners. Given the paucity of data and calculation methods applied to those data, substantial uncertainty exists in this parameter.

[2] The mean value of two available data points: 0.031 and 0.042 ng/L (Sandvik, 2009).

Ecology estimated total PCBs from multiple freshwaters around the state using the same SPMD method (Johnson, 2007). The lowest mean concentration from this source (0.008 ng/L) was run through the model as an example of a lower limit of uncertainty on total PCBs in water. The same was done using the highest mean from two stations located upstream of the Lower Duwamish Waterway Superfund Site (0.495 ng/L) as an upper limit of uncertainty (King County, 2009b). The latter data were collected using grab samples one meter above bottom and one meter below surface. The resulting range of total PCB concentrations in northern pikeminnow tissue was 4.7 to 290 ug/kg. This large variability highlights the need for more congener analysis of Lake Washington water samples.

The food web model analyses led to the conclusion that reductions in sediment PCB concentrations would substantially reduce PCB bioaccumulation in northern pikeminnow, and presumably other species. This is a conservative modeling exercise since, as the sediment core demonstrates, the bioavailable 0-10 cm sediment segment has higher average PCB concentrations. Because PCB water data for Lake Washington are scarce and only exist from SPMD collection methods, quantification of true water concentrations is an important data gap.

## PCB Trends

At first glance, total PCB concentrations in south Lake Washington surface sediments appear to be decreasing relative to the historical data (Figures 2 and 3). However, comparing PCB concentrations from the current study to historical concentrations is inappropriate for at least two reasons:

- The elevated concentrations found in sediments at the south end of the study area, near the DNR property and the Boeing Renton Facility (Weston, 1997,1999), were collected on a much finer scale. For example, some samples were collected right at the discharge flume and stormwater outfalls. The current study collected samples further out from shore.
- The sampling interval of surface sediments was different. Historical samples were collected from the 0-10 cm layer, and this study collected samples from the 0-2 cm layer (most recent deposition).

The United States Geological Survey (USGS) collected a box core sample from north Lake Washington similar to the south Lake Washington box core sample collected for this 2009 study. The north Lake Washington core was collected just north of the 520 floating bridge, in 1998 (Van Metre et al., 2004). Figure 11 compares the USGS north Lake Washington core to Ecology’s south Lake Washington core. The USGS analyzed for PCB Aroclors, while Ecology analyzed for PCB congeners. Because of the difference in analytical methods, only a comparison of the PCB trend lines should be made.

PCB trends in both cores are quite similar. PCB concentrations in the core rise sharply between 1945 and 1955, after PCB use became prevalent in the 1930s. PCBs peak in the late 1960s and then drop dramatically around the time PCBs were banned in 1977.

In both cores, ongoing PCB sources continue at a low to moderate level for many years after the ban. Some of these low-level ongoing sources are only now being discovered. As an example, PCBs were used to increase the flexibility of building caulk across the country, and EPA has initiated a program to locate old contaminated caulking material in schools to reduce human exposures (EPA, 2010).

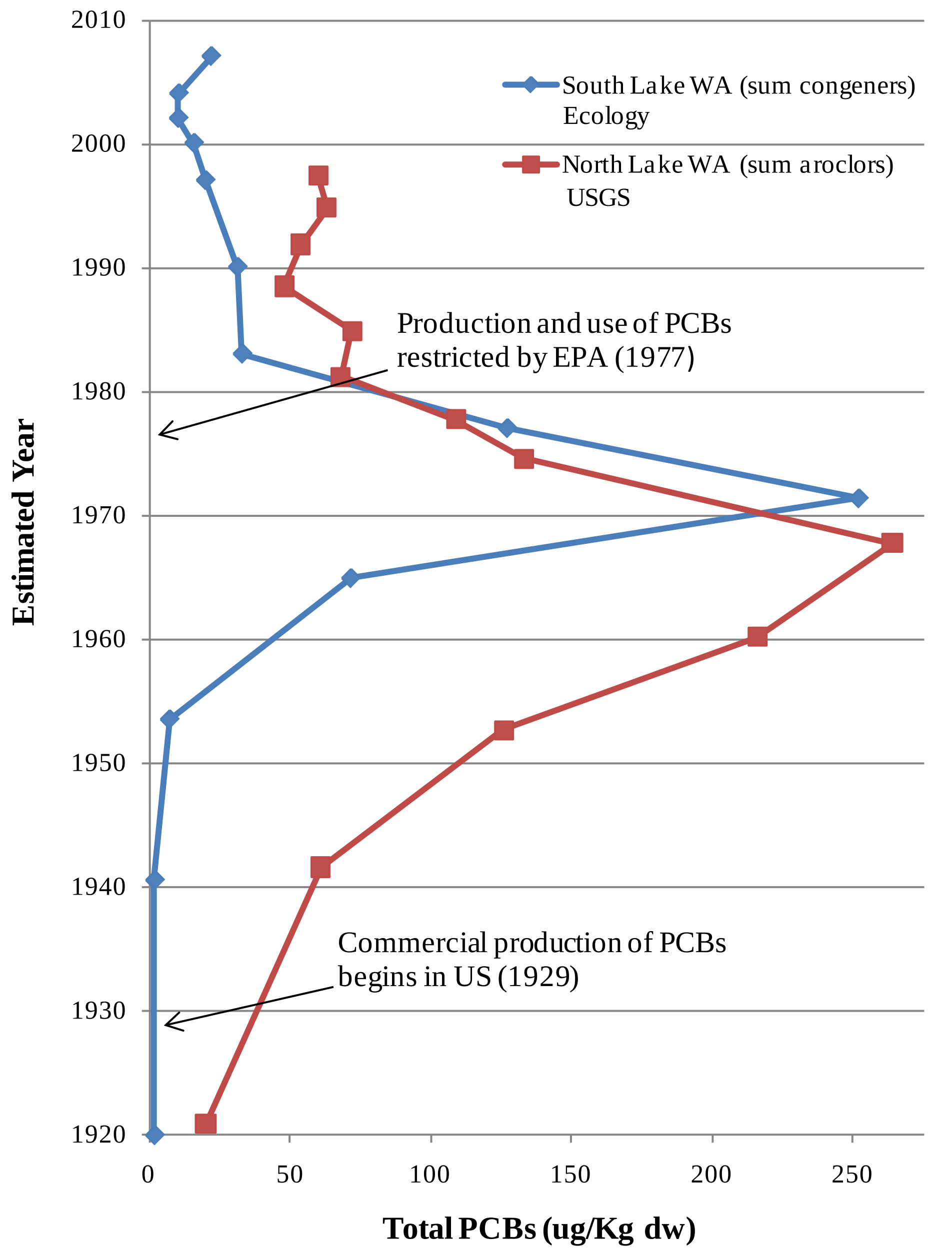


Figure 11. Comparison of North Lake Washington and South Lake Washington PCB Sediment Cores.

# Conclusions

During 2009 Ecology collected surface 0-2 cm sediment samples from 52 locations in south Lake Washington and analyzed them for PCB mixtures (Aroclors), grain size, TOC, and percent solids. PCBs were detected in over 75% of the samples. Aroclors 1254 and 1260 were the most frequently detected Aroclors. Total PCB concentrations ranged from 3.3 to 57 ug/Kg dry weight.

PCB concentrations were generally homogenous across the study area although some subtle spatial patterns are suggested. Variability in PCB concentrations was low (within a factor of 10). PCBs were strongly correlated with both fines (silt + clay) and total organic carbon. Additional sediment data are unlikely to refine these estimates or conclusively identify a single high PCB source to the southern portion of Lake Washington.

The highest surface sediment concentrations were along the western shore of the lake near highly developed upland areas and pump stations along with potential combined sewer system discharges. The lowest concentrations were along the western shoreline of Mercer Island and at the mouths of the Cedar River and Mercer Slough. Sediment input from the Cedar River appears to be cleaner than the native lake sediment.

Modeling of PCB bioaccumulation in northern pikeminnow demonstrated that 98% of the fish tissue burden is from sediment sources. The modeling exercise indicated that measured surface sediment concentrations, while low, are high enough to result in fish tissue concentrations that are potentially hazardous to human health. It appears that reductions in sediment PCB concentrations would need to occur in the biologically active zone (0-10 cm) to meet the National Toxics Rule criteria for fish tissue. True concentrations of PCBs in water are unknown; this is a current data gap.

PCBs in the sediment core followed the expected historical pattern of production, use, and ban of PCBs. PCBs were not detected in the core prior to 1941. PCB trends and magnitudes observed in this 2009 project were similar to those seen in a north lake Washington core collected by USGS in 1998.

# Recommendations

The presence of PCBs in the 0-2 cm sediment layer is evidence that ongoing sources of PCBs remain in the Lake Washington watershed. These sources may be diffuse, from aerial deposition and stormwater as they are in portions of the Spokane River system (Ecology, 2007) or they may be from point sources as found in some portions of the Lower Duwamish CERCLA[3]/ MTCA[4] cleanup site (King County, 2006).

Investigation and monitoring of PCB sources to Lake Washington are recommended to narrow down the ongoing transport pathways contributing PCBs to lake surface sediments (e.g., aerial deposition, river loading, stormwater runoff, combined sewer overflows, and resuspension of deeper lake sediments). Collection of PCB congener data in the water column would fill a current data gap. These data could then be used as inputs to a more rigorous bioaccumulation model which would describe the water and sediment quality improvements required to meet National Toxics Rule standards for fish tissue.

Additional sampling and testing of PCBs in the 0-10 cm surface sediments would provide more data for the bioaccumulation model and could help identify hotspots of contaminated sediment that may require cleanup. If the locations of elevated PCB inputs can be narrowed, use of sediment traps in combined sewer, separated sewer, and river locations may be warranted to locate distinctive upland sources such as caulking materials (EPA, 2010).

Fish tissue from Lake Washington should be monitored every five years to determine if PCB concentrations decrease over time. Working in conjunction with Washington State Department of Health, the fish tissue data could be used to re-evaluate the need for the current fish consumption advisory in Lake Washington.

[3] CERCLA - The Comprehensive Environmental Response, Compensation, and Liability Act.
[4] MTCA – Model Toxics Control Act.

*This page is purposely left blank*

# References

Arnot, JA and Gobas, FAPC, 2004. A Food Web Bioaccumulation Model for Organic Chemicals in Aquatic Ecosystems. Environmental Toxicology and Chemistry 23(10): 2343-2355.

Blakley, N., 2008. Standard Operating Procedure (SOP) for Obtaining Freshwater Sediment Samples, Version 1.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP040. www.ecy.wa.gov/programs/eap/quality.html.

Brocksmith, R., 1999. Abundance, feeding ecology, and behavior of a native piscivore northern pikeminnow (Ptychocheilus oregonensis) in Lake Washington. A thesis in fulfillment of the requirements for the degree of Master of Science. University of Washington. 104 pp.

Brown, K.W. and D.H. Caldwell, 1958. Metropolitan Seattle Sewerage and Drainage Survey. A Report for the City of Seattle, King County and the State of Washington. Brown and Caldwell Consulting Engineers, Seattle WA.

Burkhard, L.P., 1998. Comparison of two models for predicting bioaccumulation of hydrophobic organic chemicals in a Great Lakes food web. Environmental Toxicology and Chemistry 17(3):383-393.

Chigbu, P. and T.H. Sibley, 1998. Feeding ecology of longfin smelt (Spirinchus thaleichthys Ayres) in Lake Washington. Fisheries Research 38:109-119.

Coots, R., 2007. Vancouver Lake PCBs, Chlorinated Pesticides, and Dioxins in Fish Tissue and Sediment. Washington State Department of Ecology, Olympia, WA. Publication No. 07-03-017. www.ecy.wa.gov/biblio/0703017.html.

Coots, R. and B. Era-Miller, 2005. Lake Chelan DDT and PCBs in Fish Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. Publication No. 05-03-014. www.ecy.wa.gov/biblio/0503014.html.

DOH, 2004. Final Report: Evaluation of Contaminants in Fish from Lake Washington, King County, Washington. Washington State Department of Health, Olympia, WA.

Ecology, 2003a. Sediment Sampling and Analysis Plan Appendix. Washington State Department of Ecology, Olympia, WA. Publication No. 03-09-043. www.ecy.wa.gov/biblio/0309043.html.

Ecology, 2007. PCB TMDL Stormwater Loading Analysis. Washington State Department of Ecology, Olympia, WA. Publication No. 07-03-055. www.ecy.wa.gov/biblio/0703055.html.

EPA, 2010. PCBs in Caulk in Older Buildings. U.S. Environmental Protection Agency. www.epa.gov/pcbsincaulk/ Accessed January 28, 2010.

Era-Miller, B., 2009. Quality Assurance Project Plan: General Characterization of PCBs in South Lake Washington Sediments. Washington State Department of Ecology, Olympia, WA. Publication No. 09-03-106. www.ecy.wa.gov/biblio/0903106.html.

Felton,V., G. Tixier, F. Guerold, V. De Crespin De Billy and O. Dangles, 2008. Quantification of diet variability in a stream amphipod: implications for ecosystem functioning. Fundamental and Applied Limnology. 170(4):303-313.

Furl, C. and C. Meredith, 2008. Standard Operating Procedure (SOP) for Collection of Freshwater Sediment Core Samples Using a Box or KB Corer, Version 1.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP038. www.ecy.wa.gov/programs/eap/quality.html.

Furl, C., C. Meredith, and M. Friese, 2009. Determination of PBT Chemical Trends in Selected Washington Lakes Using Age-Dated Sediment Cores: 2008 Sampling Results. Washington State Department of Ecology, Olympia, WA. Publication No. 09-03-030. www.ecy.wa.gov/biblio/0903030.html.

Gobas, Frank A.P.C., 1993. A model for predicting the bioaccumulation of hydrophobic organic chemicals in aquatic food-webs: application to Lake Ontario. Ecological Modelling, 69:1-17.

Hampton, S.E., M.D. Scheuerell, and D.E. Schindler, 2006. Coalescence in the Lake Washington story: Interaction strengths in a planktonic food web. Limnology and Oceanography. 51(5):2042-2051.

Johnson, A., 2007. Standard Operating Procedure for Using Semipermeable Membrane Devices to Monitor Hydrophobic Organic Compounds in Surface Water. Washington State Department of Ecology, Olympia, WA. SOP Number EAP040. www.ecy.wa.gov/programs/eap/quality.html.

King County, 2006. Lower Duwamish Waterway Source Control Project, King County International Airport, Slip 4 Early Action Site Source Control Monitoring Report - June 2006 Stormwater Vault Sediment Sampling. King County Department of Natural Resources, Wastewater Treatment Division. www.kingcounty.gov/environment/wastewater/IndustrialWaste/SourceControl/Duwamish/~/media/environment/wastewater/IndustrialWasteProgram/docs/Duwamish/Documents%20and%20Reports/IntlArptSmplg06/KCIA_Jun06_SWVault_Sed_Rpt.ashx

King County, 2009a. Lake Washington Overview. King County Natural Resources and Parks, Water and Land Resources Division. Accessed January 12, 2009. www.kingcounty.gov/environment/waterandland/lakes/lakes-of-king-county/washington.aspx

King County, 2009b. Personal communication. Discussion between Jenée Colton and Debra Williston of King County, DNRP on 12/14/2009 regarding data collected in support of the Lower Duwamish Waterway RI/FS.

King County, 2010. Combined Sewer Overflow map available online at: www.kingcounty.gov/environment/wastewater/CSO/RealTime/SeattleOverview.aspx

Mazur, M., 2004. Linking visual foraging with temporal prey distributions to model trophic interactions in Lake Washington. A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy. University of Washington, School of Aquatic and Fishery Sciences.

McIntyre, J.K., 2004. Bioaccumulation of metals and organochlorines in the food web of Lake Washington. A thesis submitted in partial fulfillment of the degree of Master of Science. University of Washington.

Mecom, J.O., 1972. Productivity and distribution of trichoptera larvae in a Colorado mountain stream. Hydrobiologia. 40(2):151-176.

Morrison, H.A., F.A.P.C. Gobas, R. Lazar, D.M. Whittle, and G.D. Haffner, 1997. Development and verification of a benthic/pelagic food web bioaccumulation model for PCB congeners in western Lake Erie. Environmental Science and Technology. 31:3267-3273.

Morrison, H.A., D.M. Whittle, C.D. Metcalfe, and A.J. Niimi, 1999. Application of a food web bioaccumulation model for prediction of polychlorinated biphenyl, dioxin, and furan congener concentrations in Lake Ontario aquatic biota. Canadian Journal of Fisheries and Aquatic Science. 56:1389-1400.

Murtaugh, P.A., 1981. Selective predation by *Neomysis mercedis* in Lake Washington. Limnology and Oceanography. 26(3):445-453.

Norton, D., 2004. Mercury in Lake Whatcom Sediments, Spatial Distribution, Depositional History, and Tributary Inputs. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-019. www.ecy.wa.gov/biblio/0403019.html.

Olson, J.P. and W.W. Zhan, 2001. City of Seattle 2001 Combined Sewer Overflow Reduction Plan Amendment. CTE Engineers, Seattle WA.

Russell, R.W., F.A.P.C. Gobas, and G.D. Haffner, 1999. Role of chemical and ecological factors in trophic transfer of organic chemicals in aquatic food webs. Environmental Toxicology and Chemistry. 18(6):1250-1257.

Sandvik, P., 2009. Washington State Toxics Monitoring Program: Trends Monitoring for Chlorinated Pesticides, PCBs, and PBDEs in Washington Rivers and Lakes, 2007. Washington State Department of Ecology, Olympia, WA. Publication No. 09-03-013. www.ecy.wa.gov/biblio/0903013.html.

Seiders, K., C. Deligeannis and P. Sandvik, 2007. Washington State Toxics Monitoring Program: Contaminants in Fish Tissue from Freshwater Environments in 2004 and 2005. Washington State Department of Ecology, Olympia, WA. Publication No. 07-030-024. www.ecy.wa.gov/biblio/0703024.html.

Summers, R. B., M.D. Delong, and J.H. Thorp, 1997. Ontogenetic and temporal shifts in the diet of the amphipod Gammarus fasciatus, in the Ohio River. American Midland Naturalist. 137:329-336.

Tabor, R.A., E.J. Warner, K.L. Fresh, B.A. Footen, and J.R. Chan, 2007. Ontogenetic diet shifts of prickly sculpin in the Lake Washington Basin, Washington. Transactions of the American Fisheries Society 136:1801-1813.

Van Metre, P.C., 2009. Personal communication. U.S. Geological Survey.

Van Metre, P., J. Wilson, C. Fuller, E. Callender, and B. Mahler, 2004. Collection, Analysis and Age-Dating of Sediment Cores from 56 U.S. Lakes and Reservoirs Sampled by the U.S. Geological Survey.

Wertz, I., 2010. Personal communication, email on 2/19/2010. City of Seattle.

Weston, 1997. DNR Parcel Offshore Sediment Investigation Report. Submitted to The Boeing Company, Boeing Information Support Services, Energy and Environmental Affairs. Roy F. Weston Inc., Seattle, WA 98104.

Weston, 1999. Outfall, Shoreline, and Nearshore Sediments Sampling Report. Submitted to the Boeing Company, Boeing Shared Services Group, Energy and Environmental Affairs. Roy F. Weston Inc., Seattle, WA 98104.

# Appendices

*This page is purposely left blank*

# Appendix A. Glossary, Acronyms, and Abbreviations

## Glossary

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

**Benthic:** Bottom-dwelling organisms.

**Bioaccumulate:** Build up in the food chain.

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

**Combined sewer (CS) system:** A sewer system that collects both stormwater runoff and sanitary sewage in the same pipe. During dry weather, these CS systems transport wastewater directly to the sewage treatment plant. In periods of rainfall or snowmelt, however, the wastewater volume in a CS system can exceed the capacity of the sewer system or treatment plant. For this reason, CS systems are designed to overflow occasionally and discharge excess wastewater directly to nearby streams, rivers, lakes, or estuaries. CS systems contain not only stormwater but also untreated human and industrial waste, toxic materials, and debris.

**Congener:** In chemistry, congeners are related chemicals. For example, polychlorinated biphenyls (PCBs) are a group of 209 related chemicals that are called congeners.

**Grab sample:** A discrete sample from a single point in the water column or sediment surface.

**Nonpoint source:** Sources of pollution from diffuse sources, such as polluted runoff from urban stormwater or agricultural areas, which drain into surface water.

**Octanol-water partitioning coefficient ($K_{ow}$):** The octanol-water partition coefficient is the ratio of the concentration of a chemical in octanol and in water at equilibrium and at a specified temperature. Octanol is an organic solvent that is used as a surrogate for natural organic matter.

**Parameter:** Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

**Point source:** Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

**Pollution:** Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

**Polychlorinated biphenyl (PCB):** A class of organic compounds with 1 to 10 chlorine atoms attached to a biphenyl, which is a molecule composed of two benzene rings. PCBs were widely used for many applications, especially as dielectric fluids in transformers, capacitors, and coolants. PCBs are known to cause cancer and many other toxic effects to humans and other organisms. PCB production was banned by the United States Congress in 1979.

**Salmonid**: Any fish that belong to the family *Salmonidae*. Basically, any species of salmon, trout, or char.

**Sediment:** Solid fragmented material (soil and organic matter) that is transported and deposited by water and covered with water (example, river or lake bottom).

**Sediment core:** A core taken of the sediments on the bottom of a waterbody such as a lake that show a vertical profile of the sediments. Individual layers or horizons can be sliced off and analyzed for chemical content.

**Separated sewer (SS) system:** A sewer system where residential and industrial sewage is collected in separate pipes from stormwater. Stormwater is treated separately from sewage which is diverted to a wastewater treatment facility.

**Spatial distribution:** How concentrations differ among various parts of the lake.

**Stormwater:** The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

**Surface sediment:** The top layers of sediment on the bottom of a waterbody such as a lake or stream.

**Watershed:** A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

## Acronyms and Abbreviations

| | |
|---|---|
| CS | (See Glossary above) |
| DNR | Washington State Department of Natural Resources |
| KCDNRP | King County Department of Natural Resources and Parks |
| DOH | Washington State Department of Health |
| Ecology | Washington State Department of Ecology |
| EIM | Environmental Information Management database |
| EPA | U.S. Environmental Protection Agency |
| GIS | Geographic Information System software |
| GPS | Global Positioning System |
| I-90 | Interstate 90 |
| LCS | Laboratory control sample |
| MEL | Manchester Environmental Laboratory |
| MQO | Measurement quality objective |
| N (or n) | Number |
| NAD83 | North American Datum 1983 |
| NTR | National Toxics Rule |
| PBT | persistent, bioaccumulative, and toxic substance |
| PCB | polychlorinated biphenyl |
| RPD | Relative percent difference |
| RSD | Relative standard deviation |
| SOP | Standard operating procedures |
| SS | (See Glossary above) |
| TOC | Total organic carbon |
| USGS | U.S. Geological Survey |

*Units of Measurement*

| | |
|---|---|
| cm | centimeter |
| dw | dry weight |
| ft | feet |
| g | gram, a unit of mass |
| m | meter |
| mm | millimeter |
| mg/Kg | milligrams per kilogram (parts per million) |
| ng/L | nanograms per liter (parts per trillion) |
| ug/Kg | micrograms per kilogram (parts per billion) |
| ww | wet weight |

*This page is purposely left blank*

# Appendix B. Sample Information and Result Data

*This page is purposely left blank*

Table B-1. Sample Location Information and Sediment Quality Descriptions.

| Station ID | Grab # | Date | Time | Latitude NAD83 | Longitude NAD83 | Water Depth (m) | Penetration Depth (cm) | Sediment Quality Description |
|---|---|---|---|---|---|---|---|---|
| WA-01 | 1 | 2/25/09 | 9:36 | 47.58873 | -122.25536 | 13.0 | 9 | light brown silt on dense gray sediment |
| | 2 | " | 9:44 | 47.58882 | -122.25545 | 13.9 | 9 | " |
| | 3 | " | 9:52 | 47.58880 | -122.25562 | 16.2 | 10 | " |
| | Centroid Location* | | | **47.58878** | **-122.25547** | | | |
| WA-02 | 1 | 2/25/09 | 15:16 | 47.57938 | -122.25188 | 14.6 | 5 | fine to medium sand - light brown to orange |
| | 2 | " | 15:21 | 47.57964 | -122.25207 | 13.2 | 8 | " |
| | 3 | " | 15:26 | 47.57952 | -122.25205 | 13.7 | 8 | " |
| | Centroid Location | | | **47.57951** | **-122.25199** | | | |
| WA-03 | 1 | 2/25/09 | 15:40 | 47.57249 | -122.24024 | 14.7 | 9 | fine silt with slight grit |
| | 2 | " | 15:47 | 47.57274 | -122.24042 | 13.0 | 8 | " |
| | 3 | " | 15:51 | 47.57265 | -122.24023 | 11.8 | 8 | " |
| | Centroid Location | | | **47.57263** | **-122.24029** | | | |
| WA-04 | 1 | 2/24/09 | 13:40 | 47.56463 | -122.23365 | 20.8 | 5 | brown silt with a little sand over gray silty sand |
| | 2 | " | 14:02 | 47.56465 | -122.23378 | 20.4 | 7 | " |
| | 3 | " | 14:13 | 47.56442 | -122.23375 | 19.6 | 6 | " |
| | Centroid Location | | | **47.56458** | **-122.23374** | | | |
| WA-05 | 1 | 2/24/09 | 12:20 | 47.55528 | -122.23388 | 15.1 | 12 | thin brown silt layer on gritty gray sand |
| | 2 | " | 12:27 | 47.55472 | -122.23412 | 15.1 | 10 | thin brown silt layer on less course gray sand |
| | 3 | " | 12:42 | 47.55493 | -122.23402 | 15.5 | 14 | " |
| | Centroid Location | | | **47.55494** | **-122.23402** | | | |
| WA-06 | 1 | 2/24/09 | 11:54 | 47.54507 | -122.23798 | 16.1 | 10 | floc silt on sand |
| | 2 | " | 12:00 | 47.54509 | -122.23822 | 19.6 | 15 | light brown silt on gray sand with some large grains |
| | 3 | " | 12:06 | 47.54537 | -122.23822 | 20.8 | 15 | " |
| | Centroid Location | | | **47.54517** | **-122.23813** | | | |
| WA-07 | 1 | 3/3/09 | 10:15 | 47.53892 | -122.24458 | 16.1 | 6 | light brown mud over sandy mud with some leaves and debris |
| | 2 | " | 10:20 | 47.53886 | -122.24456 | 14.8 | 10 | light brown mud over sandy mud |
| | 3 | " | 10:25 | 47.53892 | -122.24445 | 15.3 | 14 | " |

| Station ID | Grab # | Date | Time | Latitude NAD83 | Longitude NAD83 | Water Depth (m) | Penetration Depth (cm) | Sediment Quality Description |
|---|---|---|---|---|---|---|---|---|
| | | | Centroid Location* | **47.53890** | **-122.24453** | | | |
| WA-08 | 1 | 2/24/09 | 10:50 | 47.52867 | -122.23665 | 20 | 14 | floc on sand |
| | 2 | " | 10:57 | 47.52868 | -122.23671 | 20.6 | 15 | floc on silty sand |
| | 3 | " | 11:05 | 47.52879 | -122.23676 | 18.7 | 10 | floc on silt |
| | | | Centroid Location | **47.52872** | **-122.23670** | | | |
| WA-09 | 1 | 2/24/09 | 10:12 | 47.52507 | -122.22310 | 16.6 | 17 | floc on brown silty sand |
| | 2 | " | 10:24 | 47.52481 | -122.22353 | 14.5 | 10 | floc on sand |
| | 3 | " | 10:35 | 47.52492 | -122.22322 | 16.4 | 17 | floc on brown silty sand |
| | | | Centroid Location | **47.52494** | **-122.22324** | | | |
| WA-10 | 1 | 3/4/09 | 10:39 | 47.53277 | -122.21435 | 17.2 | 17 | 1 cm light brown muddy silt over gray muddy silt |
| | 2 | " | 10:43 | 47.53282 | -122.21456 | 11.7 | 16 | " |
| | 3 | " | 10:47 | 47.53260 | -122.21442 | 17.4 | 17 | " |
| | | | Centroid Location | **47.53274** | **-122.21445** | | | |
| WA-11 | 1 | 3/4/09 | 15:17 | 47.54142 | -122.20828 | 11.3 | 17 | thin brown mud layer over gray mud with black specks, hairs, few clams |
| | 2 | " | 15:21 | 47.54159 | -122.20796 | 12.0 | 17 | thin brown mud over gray mud with minor woody debris |
| | 3 | " | 15:24 | 47.54169 | -122.20820 | 10.2 | 17 | " |
| | | | Centroid Location | **47.54158** | **-122.20814** | | | |
| WA-12 | 1 | 3/4/09 | 14:55 | 47.55141 | -122.20842 | 10.2 | 15 | thin brown mud over gray mud with sandy bottom and a few clams |
| | 2 | " | 14:58 | 47.55129 | -122.20849 | 10.2 | 17 | " |
| | 3 | " | 15:02 | 47.55122 | -122.20833 | 11.0 | 17 | thin brown mud layer over gray mud with black specks and hairs |
| | | | Centroid Location | **47.55130** | **-122.20841** | | | |
| WA-13 | 1 | 3/4/09 | 14:37 | 47.56128 | -122.20687 | 10.9 | 17 | soupy thin mud brown layer over gray mud with some shell bits |
| | 2 | " | 14:41 | 47.56124 | -122.20676 | 11.3 | 17 | " |
| | 3 | " | 14:45 | 47.56131 | -122.20700 | 10.7 | 17 | " |
| | | | Centroid Location | **47.56128** | **-122.20687** | | | |
| WA-14 | 1 | 3/4/09 | 14:03 | 47.56938 | -122.20478 | 10.0 | 15 | thin brown mud layer over gray mud |

| Station ID | Grab # | Date | Time | Latitude NAD83 | Longitude NAD83 | Water Depth (m) | Penetration Depth (cm) | Sediment Quality Description |
|---|---|---|---|---|---|---|---|---|
| | 2 | " | 14:07 | 47.56933 | -122.20441 | 12.0 | 17 | " |
| | 3 | " | 14:11 | 47.56931 | -122.20482 | 10.1 | 16 | " |
| | | Centroid Location* | | **47.56934** | **-122.20465** | | | |
| WA-15 | 1 | 3/4/09 | 13:46 | 47.57701 | -122.19966 | 11.9 | 11 | thin brown mud over gray mud w/sandy bottom and a few clams |
| | 2 | " | 13:50 | 47.57711 | -122.19972 | 10.2 | 4 | thin brown mud over gray mud w/sandy bottom w/pebbles and a few clams |
| | 3 | " | 13:53 | 47.57688 | -122.19960 | 12.1 | 17 | thin brown mud layer over gray mud |
| | | Centroid Location | | **47.57701** | **-122.19966** | | | |
| WA-16 | 1 | 3/4/09 | 13:30 | 47.57634 | -122.19319 | 8.5 | 17 | thin brown mud layer over gray mud with black specks |
| | 2 | " | 13:33 | 47.57640 | -122.19336 | 8.7 | 17 | " |
| | 3 | " | 13:37 | 47.57620 | -122.19336 | 9.0 | 17 | thin brown mud layer over gray mud with black specks and many clams |
| | | Centroid Location | | **47.57632** | **-122.19331** | | | |
| WA-17 | 1 | 3/4/09 | 13:14 | 47.57343 | -122.19389 | 9.0 | 17 | thin brown mud layer over gray mud with black specks |
| | 2 | " | 13:18 | 47.57344 | -122.19412 | 9.8 | 17 | " |
| | 3 | " | 13:21 | 47.57316 | -122.19387 | 8.3 | 17 | " |
| | | Centroid Location | | **47.57334** | **-122.19397** | | | |
| WA-18 | 1 | 2/25/09 | 10:12 | 47.58113 | -122.26754 | 49.3 | 17 | dark brown layer over medium gray soupy mud |
| | 2 | " | 10:21 | 47.58090 | -122.26792 | 49.2 | 17 | " |
| | 3 | " | 10:36 | 47.58110 | -122.26771 | 49.2 | 17 | " |
| | | Centroid Location | | **47.58105** | **-122.26771** | | | |
| WA-19 | 1 | 3/4/09 | 14:20 | 47.56641 | -122.19730 | 11.6 | 17 | thin brown mud layer over gray mud with black specks and hairs |
| | 2 | " | 14:23 | 47.56670 | -122.19717 | 11.3 | 17 | thin brown mud over gray mud with minor woody debris |
| | 3 | " | 14:27 | 47.56651 | -122.19726 | 11.6 | 17 | " |
| | | Centroid Location | | **47.56653** | **-122.19724** | | | |
| WA-20 | 1 | 3/4/09 | 12:08 | 47.55976 | -122.19360 | 14.3 | 17 | very thin light brown silty layer over gray mud |
| | 2 | " | 12:14 | 47.55983 | -122.19390 | 15.9 | 17 | " |
| | 3 | " | 12:18 | 47.55982 | -122.19362 | 14.4 | 17 | " |

| Station ID | Grab # | Date | Time | Latitude NAD83 | Longitude NAD83 | Water Depth (m) | Penetration Depth (cm) | Sediment Quality Description |
|---|---|---|---|---|---|---|---|---|
| | | | Centroid Location* | **47.55980** | **-122.19367** | | | |
| WA-21 | 1 | 3/4/09 | 11:48 | 47.55122 | -122.19843 | 19.6 | 17 | light brown silty layer (0.5 cm) over gray mud |
| | 2 | " | 11:52 | 47.55124 | -122.19802 | 14.7 | 16 | " |
| | 3 | " | 11:56 | 47.55127 | -122.19835 | 19.3 | 17 | " |
| | | | Centroid Location | **47.55124** | **-122.19827** | | | |
| WA-22 | 1 | 3/4/09 | 11:27 | 47.54249 | -122.19774 | 16.3 | 11 | light brown silty layer (2 cm) over gray mud with some woody debris |
| | 2 | " | 11:35 | 47.54262 | -122.19750 | 12.6 | 17 | light brown silty layer (2 cm) over gray mud and some sand |
| | 3 | " | 11:38 | 47.54262 | -122.19761 | 14.5 | 17 | " |
| | | | Centroid Location | **47.54258** | **-122.19760** | | | |
| WA-23 | 1 | 3/4/09 | 11:01 | 47.53663 | -122.20405 | 8.5 | 5 | light brown silty layer (0.5 cm) over gray mud with some woody debris |
| | 2 | " | 11:08 | 47.53680 | -122.20379 | 9.0 | 12 | " |
| | 3 | " | 11:14 | 47.53669 | -122.20433 | 9.4 | 17 | " |
| | | | Centroid Location | **47.53672** | **-122.20405** | | | |
| WA-24 | 1 | 3/4/09 | 10:18 | 47.52796 | -122.20854 | 9.5 | 15 | light brown silty layer (1.5 cm) over gray mud with some twigs |
| | 2 | " | 10:22 | 47.52800 | -122.20886 | 9.8 | 15 | light brown silty layer (1.5 cm) over gray mud |
| | 3 | " | 10:26 | 47.52777 | -122.20889 | 10.0 | 16 | " |
| | | | Centroid Location | **47.52791** | **-122.20875** | | | |
| WA-25 | 1 | 3/4/09 | 9:49 | 47.52230 | -122.21171 | 13.9 | 17 | light brown silty layer (2 cm) over gray mud |
| | 2 | " | 9:53 | 47.52250 | -122.21144 | 14.1 | 17 | " |
| | 3 | " | 9:57 | 47.52249 | -122.21174 | 14.3 | 17 | " |
| | | | Centroid Location | **47.52244** | **-122.21162** | | | |
| WA-26 | 1 | 3/4/09 | 9:27 | 47.51321 | -122.20728 | 18.5 | 15 | light brown silty layer (1 cm) over gray mud with some twigs |
| | 2 | " | 9:31 | 47.51335 | -122.20740 | 17.5 | 8 | light brown silty layer (1 cm) over gray mud |
| | 3 | " | 9:35 | 47.51323 | -122.20716 | 18.3 | 12 | light brown silty layer (1 cm) over gray mud with some twigs |
| | | | Centroid Location | **47.51327** | **-122.20728** | | | |
| WA-27 | 1 | 3/3/09 | 17:11 | 47.50661 | -122.20515 | 9.6 | 15 | light brown silty layer (0.5 cm) over gray mud with some woody debris |

| Station ID | Grab # | Date | Time | Latitude NAD83 | Longitude NAD83 | Water Depth (m) | Penetration Depth (cm) | Sediment Quality Description |
|---|---|---|---|---|---|---|---|---|
| | 2 | " | 17:19 | 47.50671 | -122.20530 | 10.7 | 17 | " |
| | 3 | " | 17:21 | 47.50674 | -122.20537 | 10.0 | 17 | " |
| | | Centroid Location* | | **47.50668** | **-122.20528** | | | |
| WA-28 | 1 | 3/3/09 | 16:21 | 47.50282 | -122.21108 | 14.0 | 17 | light brown silty layer (0.5 cm) over dark brown mud |
| | 2 | " | 16:25 | 47.50279 | -122.21116 | 13.9 | 17 | " |
| | 3 | " | 16:29 | 47.50285 | -122.21121 | 14.2 | 17 | light brown silty layer (0.5 cm) over dark brown mud with some detritus |
| | | Centroid Location | | **47.50282** | **-122.21115** | | | |
| WA-29 | 1 | 3/3/09 | 15:37 | 47.50421 | -122.22121 | 18.6 | 10 | gritty gray silt with a lot of detritus |
| | 2 | " | 15:43 | 47.50401 | -122.22151 | 13.8 | 11 | " |
| | 3 | " | 15:48 | 47.50384 | -122.22142 | 13.3 | 12 | silty sand with a lot of small woody debris |
| | | Centroid Location | | **47.50402** | **-122.22136** | | | |
| WA-30 | 1 | 2/25/09 | 10:56 | 47.58919 | -122.28314 | 17.7 | 5 | dark brown top layer over gray medium density mud |
| | 2 | " | 11:05 | 47.58917 | -122.28297 | 20.1 | 10 | " |
| | 3 | " | 11:12 | 47.58897 | -122.28291 | 21.7 | 12 | dark brown top layer over dark gray medium density mud |
| | | Centroid Location | | **47.58913** | **-122.28301** | | | |
| WA-31 | 1 | 2/25/09 | 11:25 | 47.58129 | -122.28341 | 16.2 | 8 | thin brown top layer over medium gray silty sand |
| | 2 | " | 11:31 | 47.58118 | -122.28356 | 13.2 | 10 | " |
| | 3 | " | 11:35 | 47.58110 | -122.28351 | 12.1 | 5 | " |
| | | Centroid Location | | **47.58119** | **-122.28348** | | | |
| WA-33A | 1 | 2/25/09 | 14:29 | 47.57045 | -122.27325 | 17.7 | 17 | very fine silt |
| | 2 | " | 14:36 | 47.57026 | -122.27323 | 16.5 | 17 | " |
| | 3 | " | 14:54 | 47.57028 | -122.27351 | 14.4 | 16 | " |
| | | Centroid Location | | **47.57034** | **-122.27332** | | | |
| WA-34 | 1 | 2/24/09 | 16:01 | 47.56358 | -122.26379 | 14.6 | 15 | very wet silt |
| | 2 | " | 16:06 | 47.56355 | -122.26395 | 14.4 | 17 | " |
| | 3 | " | 16:10 | 47.56350 | -122.26418 | 13.7 | 13 | " |
| | | Centroid Location | | **47.56355** | **-122.26395** | | | |
| WA-35 | 1 | 2/24/09 | 15:33 | 47.55753 | -122.25774 | 12.5 | 17 | silt with old wood |

| Station ID | Grab # | Date | Time | Latitude NAD83 | Longitude NAD83 | Water Depth (m) | Penetration Depth (cm) | Sediment Quality Description |
|---|---|---|---|---|---|---|---|---|
| | 2 | " | 15:38 | 47.55762 | -122.25762 | 13.1 | 17 | " |
| | 3 | " | 15:44 | 47.55756 | -122.25760 | 12.8 | 17 | " |
| | Centroid Location* | | | **47.55757** | **-122.25766** | | | |
| WA-36 | 1 | 2/24/09 | 13:15 | 47.56221 | -122.24922 | 20.8 | 17 | brown silt layer over course sand |
| | 2 | " | 13:20 | 47.56213 | -122.24922 | 21.4 | 8 | " |
| | 3 | " | 13:26 | 47.56212 | -122.24915 | 22.5 | 8 | " |
| | Centroid Location | | | **47.56215** | **-122.24920** | | | |
| WA-37 | 1 | 2/25/09 | 16:09 | 47.55227 | -122.24585 | 15.4 | 10 | thin brown silty top layer over gray gritty mud |
| | 2 | " | 16:14 | 47.55206 | -122.24586 | 17.5 | 5 | " |
| | 3 | " | 16:21 | 47.55224 | -122.24613 | 12.0 | 13 | " |
| | Centroid Location | | | **47.55220** | **-122.24594** | | | |
| WA-38 | 1 | 3/3/09 | 10:35 | 47.54437 | -122.25510 | 11.7 | 8 | light brown mud layer (1 cm) over gray sand with some bits of shell |
| | 2 | " | 10:39 | 47.54419 | -122.25520 | 12.5 | 11 | " |
| | 3 | " | 10:44 | 47.54426 | -122.25508 | 12.6 | 14 | " |
| | Centroid Location | | | **47.54427** | **-122.25513** | | | |
| WA-39 | 1 | 3/3/09 | 11:26 | 47.53922 | -122.25765 | 21.3 | 10 | silty sand layer over rocks |
| | 2 | " | 11:54 | 47.53918 | -122.25778 | 19.3 | 4 | thin silt layer over rocks |
| | 3 | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | Centroid Location | | | **47.53920** | **-122.25771** | | | |
| WA-40 | 1 | 3/3/09 | 13:46 | 47.53019 | -122.26106 | 13 | 17 | grayish brown homogenous soft mud with slight oily sheen |
| | 2 | " | 13:50 | 47.53025 | -122.26132 | 10.8 | 14 | " |
| | 3 | " | 13:54 | 47.53032 | -122.26102 | 14.5 | 17 | " |
| | Centroid Location | | | **47.53026** | **-122.26112** | | | |
| WA-41 | 1 | 3/3/09 | 13:24 | 47.52228 | -122.25951 | 12.5 | 17 | rusty brown top layer (0.5 cm) over medium gray mud |
| | 2 | " | 13:29 | 47.52265 | -122.25960 | 12.0 | 17 | " |
| | 3 | " | 13:33 | 47.52260 | -122.25963 | 12.0 | 17 | " |
| | Centroid Location | | | **47.52252** | **-122.25957** | | | |
| WA-42 | 1 | 3/3/09 | 14:08 | 47.51785 | -122.25414 | 15.4 | 12 | light brown organic layer over gray mud |

| Station ID | Grab # | Date | Time | Latitude NAD83 | Longitude NAD83 | Water Depth (m) | Penetration Depth (cm) | Sediment Quality Description |
|---|---|---|---|---|---|---|---|---|
| | 2 | " | 14:12 | 47.51799 | -122.25416 | 18.1 | 9 | " |
| | 3 | " | 14:16 | 47.51792 | -122.25441 | 12.9 | 12 | " |
| | | Centroid Location* | | **47.51792** | **-122.25424** | | | |
| WA-43 | 1 | 3/3/09 | 14:27 | 47.51294 | -122.24589 | 13.2 | 16 | light brown (0.5 cm) layer with some leaves over gray thick mud |
| | 2 | " | 14:32 | 47.51295 | -122.24585 | 13.4 | 17 | " |
| | 3 | " | 14:36 | 47.51286 | -122.24583 | 13.1 | 17 | " |
| | | Centroid Location | | **47.51292** | **-122.24584** | | | |
| WA-44 | 1 | 3/3/09 | 15:10 | 47.50920 | -122.23292 | 20.0 | 9 | gritty silt layer (2 cm) over light brown gray |
| | 2 | " | 15:13 | 47.50903 | -122.23319 | 15.0 | 10 | gritty silt layer (2 cm) over light brown gray with peat layer |
| | 3 | " | 15:17 | 47.50927 | -122.23331 | 16.2 | 14 | " |
| | | Centroid Location | | **47.50917** | **-122.23314** | | | |
| WA-45 | 1 | 3/3/09 | 9:48 | 47.53213 | -122.25031 | 36.6 | 17 | fluffy chocolate brown layer (1 cm) over gray mud |
| | 2 | " | 9:57 | 47.53243 | -122.25024 | 36.7 | 17 | " |
| | 3 | " | 10:03 | 47.53222 | -122.25013 | 36.7 | 17 | " |
| | | Centroid Location | | **47.53225** | **-122.25023** | | | |
| WA-46 | 1 | 3/3/09 | 14:46 | 47.51672 | -122.23277 | 31.0 | 17 | silty brown layer (0.5 cm) over dark brown |
| | 2 | " | 14:54 | 47.51659 | -122.23292 | 31.1 | 17 | silty light brown layer (3 cm) over dark brown |
| | 3 | " | 14:59 | 47.51687 | -122.23267 | 31.0 | 17 | silty light brown layer (3.5 cm) over dark brown |
| | | Centroid Location | | **47.51673** | **-122.23277** | | | |
| WA-47 | 1 | 2/24/09 | 16:31 | 47.56955 | -122.25415 | 47.9 | 17 | watery silt |
| | 2 | " | 16:37 | 47.57002 | -122.25413 | 47.5 | 17 | very fine soupy silt |
| | 3 | " | 16:45 | 47.56972 | -122.25385 | 47.9 | 17 | " |
| | | Centroid Location | | **47.56974** | **-122.25404** | | | |
| WA-48 | 1 | 2/24/09 | 15:07 | 47.56410 | -122.26170 | 23.4 | 5 | silt on rocks |
| | 2 | " | 15:14 | 47.56423 | -122.26188 | 23.0 | 10 | silty brown over gray mud |
| | 3 | " | 15:21 | 47.56421 | -122.26186 | 23.0 | 4.5 | silt on rocks |
| | | Centroid Location | | **47.56418** | **-122.26182** | | | |
| WA-49 | 1 | 2/24/09 | 14:40 | 47.56628 | -122.25828 | 43.6 | 17 | silty brown layer (2.5 cm) over gray mud |

| Station ID | Grab # | Date | Time | Latitude NAD83 | Longitude NAD83 | Water Depth (m) | Penetration Depth (cm) | Sediment Quality Description |
|---|---|---|---|---|---|---|---|---|
| | 2 | " | 14:47 | 47.56629 | -122.25815 | 43.9 | 17 | " |
| | 3 | " | 14:56 | 47.56641 | -122.25811 | 44.5 | 17 | " |
| | | Centroid Location* | | **47.56633** | **-122.25818** | | | |
| WA-50 | 1 | 3/3/09 | 16:40 | 47.50947 | -122.21753 | 27.8 | 17 | silty light brown top layer (1 cm), gray underneath |
| | 2 | " | 16:44 | 47.50942 | -122.21756 | 27.8 | 17 | " |
| | 3 | " | 16:48 | 47.50936 | -122.21774 | 27.8 | 17 | " |
| | | Centroid Location | | **47.50942** | **-122.21760** | | | |
| WA-51 | 1 | 3/3/09 | 16:00 | 47.50507 | -122.21524 | 20.7 | 17 | silty light brown top layer (0.5 cm), dark brown underneath |
| | 2 | " | 16:06 | 47.50506 | -122.21559 | 20.7 | 17 | " |
| | 3 | " | 16:10 | 47.50500 | -122.21521 | 20.5 | 17 | " |
| | | Centroid Location | | **47.50504** | **-122.21532** | | | |
| WA-52 | 1 | 3/3/09 | 16:57 | 47.50749 | -122.20869 | 20.3 | 17 | silty light brown top layer (0.5 cm), gray underneath |
| | 2 | " | 17:00 | 47.50759 | -122.20847 | 20.4 | 17 | |
| | 3 | " | 17:04 | 47.50747 | -122.20860 | 20.1 | 17 | |
| | | Centroid Location | | **47.50753** | **-122.20857** | | | |
| WA-53 | 1 | 3/4/09 | 15:41 | 47.50297 | -122.21596 | 1.6 | 15 | gray brown silty mud (1 cm) over gray with organic debris and milfoil |
| | 2 | " | 15:46 | 47.50286 | -122.21607 | 1.6 | 7 | gray brown silty mud (1 cm) over gray with more organic debris |
| | 3 | " | 15:50 | 47.50294 | -122.21602 | 1.7 | 16 | gray brown silty mud (1 cm) over gray with organic debris and milfoil |
| | | Centroid Location | | **47.50293** | **-122.21601** | | | |

* = Centroid location used in Ecology's EIM database.
NAD83 = North American Datum 1983

Table B-2. Sediment Chemistry Results for South Lake Washington Sediments (ug/Kg dw, part per billion).

| Site Name: | WA-01 | | WA-02 | | WA-03 | | WA-04 | | WA-05 | | WA-06 | | WA-07 | | WA-08 | | WA-09 | | WA-10 | | WA-11 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample No.: | 0902007-01 | | 0902007-02 | | 0902007-03 | | 0902007-04 | | 0902007-05 | | 0902007-06 | | 0902007-07 | | 0902007-08 | | 0902007-09 | | 0902007-10 | | 0902007-11 | |
| % Solids | 41 | | 67.5 | | 50.8 | | 47.8 | | 57.4 | | 37.8 | | 37.6 | | 35.1 | | 33.5 | | 20.6 | | 15.8 | |
| % TOC | 1.25 | | 0.37 | | 1.06 | | 1.26 | | 0.84 | | 1.83 | | 1.92 | | 2.39 | | 2.64 | | 4.59 | | 4.26 | |
| *Grain Size* | | | | | | | | | | | | | | | | | | | | | | |
| % Gravel | 7.65 | | 8.38 | | 5.60 | | 2.24 | | 11.3 | | 1.05 | | 3.78 | | 0.15 | | 0.25 | | 0.00 | | 0.00 | |
| % Sand | 80.5 | | 95.2 | | 83.0 | | 79.4 | | 81.1 | | 67.5 | | 74.5 | | 66.1 | | 61.7 | | 57.6 | | 53.2 | |
| % Silt | 16.8 | | 5.93 | | 14.2 | | 17.5 | | 11.4 | | 22.9 | | 23.1 | | 21.5 | | 43.3 | | 36.6 | | 43.0 | |
| % Clay | 1.89 | | 0.82 | | 1.06 | | 2.21 | | 1.96 | | 3.25 | | 3.92 | | 3.09 | | 4.99 | | 4.76 | | 5.54 | |
| % Fines | 18.7 | | 6.75 | | 15.3 | | 19.7 | | 13.4 | | 26.2 | | 27 | | 24.6 | | 48.3 | | 41.4 | | 48.5 | |
| *PCBs* | | | | | | | | | | | | | | | | | | | | | | |
| Aroclor 1016 | **3** | **J** | 1.8 | U | 2.4 | U | 2.5 | U | 2.1 | U | 3.1 | U | 3.3 | U | 3.5 | U | 3.7 | U | 6 | U | 7.8 | U |
| Aroclor 1221 | 3 | U | 1.8 | U | 4.9 | UJ | 5.1 | UJ | 4.2 | UJ | 3.1 | U | 3.3 | U | 3.5 | U | 3.7 | U | 6 | U | 7.8 | U |
| Aroclor 1232 | 3 | U | 1.8 | U | 6.2 | UJ | 6.7 | UJ | 4.2 | UJ | 6.2 | UJ | 3.3 | U | 4.2 | UJ | 7.4 | UJ | 7.3 | UJ | 12 | UJ |
| Aroclor 1242 | 3 | U | 1.8 | U | 2.4 | U | 2.5 | U | 3.4 | UJ | 3.1 | U | 3.3 | U | 3.5 | U | 3.7 | U | 6 | U | 7.8 | U |
| Aroclor 1248 | 3 | U | 1.8 | U | 2.4 | U | 2.5 | U | 2.1 | U | 3.1 | U | 3.3 | U | 3.5 | U | 3.7 | U | 6 | U | 7.8 | U |
| Aroclor 1254 | **5.8** | | 1.8 | U | **8.7** | | **5.6** | | **4.6** | | **11** | **J** | **7.2** | | **9.1** | | **12** | | **12** | | **17** | |
| Aroclor 1260 | **7.5** | | 1.8 | U | 2.4 | U | 2.5 | U | 2.1 | U | **4.1** | | 3.3 | U | **5.3** | | **6.7** | | **10** | | 7.8 | U |
| Aroclor 1262 | 6.8 | UJ | 1.8 | U | 2.4 | U | 2.5 | U | 2.1 | U | 3.9 | UJ | 3.3 | U | 4.4 | UJ | 5.8 | UJ | 8.4 | UJ | 7.8 | U |
| Aroclor 1268 | 3 | U | 1.8 | U | 2.4 | U | 2.5 | U | 2.1 | U | 3.1 | U | 3.3 | U | 3.5 | U | 3.7 | U | 6 | U | 7.8 | U |
| Total PCBs | **16.3** | **J** | 1.8 | U | **8.7** | | **5.6** | | **4.6** | | **15** | **J** | **7.2** | | **14.4** | | **19** | | **22** | | **17** | |

**Bolded** values indicate analyte detections.
U = The analyte was not detected at or above the reported sample quantitation limit.
J = The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte.
UJ = The analyte was not detected at or above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately measure the analyte.

Grain Size = Gravel (>2.00 mm), Sand (0.0625 to 2.00 mm), Silt (0.0039 to 0.0625 mm), Clay (<0.0039 mm), Fines (Silt + Clay).

Table B-2. Sediment Chemistry Results for South Lake Washington Sediments (ug/Kg dw, part per billion) continued.

| Site Name: | WA-12 | | WA-13 | | WA-14 | | WA-15 | | WA-16 | | WA-17 | | WA-18 | | WA-19 | | WA-20 | | WA-21 | | WA-21 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample No.: | 0902007-12 | | 0902007-13 | | 0902007-14 | | 0902007-15 | | 0902007-16 | | 0902007-17 | | 0902007-18 | | 0902007-19 | | 0902007-20 | | 0902007-21 | | 0902007-55 | |
| % Solids | 17.1 | | 20.5 | | 21 | | 15.9 | | 19.5 | | 17.6 | | 17.2 | | 13.3 | | 15.6 | | 23 | | 23.9 | |
| % TOC | 4.05 | | 4.56 | | 3.96 | | 6.02 | | 7.4 | | 7.37 | | 4.17 | | 6.23 | | 4.24 | | 5.16 | | 4.67 | |
| *Grain Size* | | | | | | | | | | | | | | | | | | | | | | |
| % Gravel | 0.00 | | 0.00 | | 0.00 | | 0.00 | | 0.00 | | 0.00 | | 0.00 | | 0.95 | | 0.00 | | 0.00 | | 0.00 | |
| % Sand | 49.1 | | 42.2 | | 62.1 | | 33.0 | | 25.6 | | 54.4 | | 44.5 | | 62.8 | | 48.8 | | 70.2 | | 64.0 | |
| % Silt | 51.1 | | 54.7 | | 39.9 | | 59.5 | | 71.2 | | 44.6 | | 41.1 | | 36.1 | | 46.4 | | 30.5 | | 35.5 | |
| % Clay | 7.87 | | 11.8 | | 7.71 | | 7.90 | | 8.09 | | 4.65 | | 6.25 | | 6.93 | | 8.4 | | 4.77 | | 5.32 | |
| % Fines | 59 | | 66.5 | | 47.6 | | 67.4 | | 79.3 | | 49.3 | | 47.4 | | 43 | | 54.8 | | 35.3 | | 40.8 | |
| *PCBs* | | | | | | | | | | | | | | | | | | | | | | |
| Aroclor 1016 | 7.2 | U | 6.1 | U | 5.8 | U | 7.8 | U | 6.4 | U | 7.1 | U | 7.2 | U | 9.3 | U | 8 | U | 5.4 | U | 5.1 | U |
| Aroclor 1221 | 7.2 | U | 12 | UJ | 5.8 | U | 16 | UJ | 13 | UJ | 7.1 | U | 12 | UJ | 9.3 | U | 9.5 | UJ | 6.5 | UJ | 6.2 | UJ |
| Aroclor 1232 | 8.6 | UJ | 12 | UJ | 12 | UJ | 7.8 | U | 7.7 | UJ | 11 | UJ | 12 | UJ | 11 | UJ | 16 | UJ | 11 | UJ | 6.2 | UJ |
| Aroclor 1242 | 7.2 | U | 6.1 | U | 5.8 | U | 7.8 | U | 6.4 | U | 7.1 | U | 7.2 | U | 9.3 | U | 8 | U | 5.4 | U | 5.1 | U |
| Aroclor 1248 | 7.2 | U | 6.1 | U | 5.8 | U | 7.8 | U | 6.4 | U | 7.1 | U | 7.2 | U | 9.3 | U | 8 | U | 5.4 | U | 5.1 | U |
| Aroclor 1254 | **11** | **J** | **15** | | **9.9** | **J** | 7.8 | U | 6.4 | U | 7.1 | U | **16** | **J** | **14** | | **11** | **J** | **20** | **J** | **15** | **J** |
| Aroclor 1260 | 7.2 | U | **7.5** | | 5.8 | U | 7.8 | U | 6.4 | U | 7.1 | U | 7.2 | U | 9.3 | U | 8 | U | **6.3** | | **6.8** | |
| Aroclor 1262 | 7.2 | U | 6.1 | U | 5.8 | U | 7.8 | U | 6.4 | U | 7.1 | U | 7.2 | U | 9.3 | U | 8 | U | 5.4 | U | 5.9 | UJ |
| Aroclor 1268 | 7.2 | U | 6.1 | U | 5.8 | U | 7.8 | U | 6.4 | U | 7.1 | U | 7.2 | U | 9.3 | U | 8 | U | 5.4 | U | 5.1 | U |
| Total PCBs | **11** | **J** | **23** | | **9.9** | **J** | 7.8 | U | 6.4 | U | 7.1 | U | **16** | **J** | **14** | | **11** | **J** | **26** | **J** | **22** | **J** |

**Bolded** values indicate analyte detections.
U = The analyte was not detected at or above the reported sample quantitation limit.
J = The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte.
UJ = The analyte was not detected at or above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately measure the analyte.

Grain Size = Gravel (>2.00 mm), Sand (0.0625 to 2.00 mm), Silt (0.0039 to 0.0625 mm), Clay (<0.0039 mm), Fines (Silt + Clay).

Table B-2. Sediment Chemistry Results for South Lake Washington Sediments (ug/Kg dw, part per billion) continued.

| Site Name: | WA-22 | | WA-23 | | WA-24 | | WA-25 | | WA-26 | | WA-27 | | WA-28 | | WA-29 | | WA-30 | | WA-31 | | WA-33A | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample No:. | 0902007-22 | | 0902007-23 | | 0902007-24 | | 0902007-25 | | 0902007-26 | | 0902007-27 | | 0902007-28 | | 0902007-29 | | 0902007-30 | | 0902007-31 | | 0902007-32 | |
| % Solids | 32.4 | | 16.9 | | 24.1 | | 19.8 | | 29.1 | | 21.9 | | 47.2 | | 50.5 | | 38.8 | | 43.7 | | 16.9 | |
| % TOC | 3.18 | | 9.73 | | 3.28 | | 3.43 | | 2.68 | | 3.46 | | 2.2 | | 1.93 | | 1.43 | | 1.21 | | 4.97 | |
| *Grain Size* | | | | | | | | | | | | | | | | | | | | | | |
| % Gravel | 0.00 | | 17.7 | | 0.00 | | 0.00 | | 0.45 | | 0.00 | | 0.00 | | 0.23 | | 0.00 | | 2.82 | | 0.00 | |
| % Sand | 67.2 | | 54.0 | | 26.0 | | 46.2 | | 28.0 | | 31.5 | | 29.7 | | 74.6 | | 88.7 | | 90.9 | | 45.5 | |
| % Silt | 32.9 | | 24.4 | | 76.2 | | 52.2 | | 68.1 | | 67.8 | | 63.9 | | 23.2 | | 12.8 | | 13.2 | | 55.9 | |
| % Clay | 4.71 | | 4.27 | | 6.33 | | 7.56 | | 8.97 | | 6.95 | | 6.16 | | 2.11 | | 1.77 | | 1.52 | | 5.53 | |
| % Fines | 37.6 | | 28.7 | | 82.5 | | 59.8 | | 77.1 | | 74.8 | | 70.1 | | 25.3 | | 14.6 | | 14.7 | | 61.4 | |
| *PCBs* | | | | | | | | | | | | | | | | | | | | | | |
| Aroclor 1016 | 3.8 | U | 7.3 | U | 5.2 | U | 6.3 | U | 8.5 | UJ | 5.7 | U | 2.6 | U | 2.4 | U | 3.1 | U | 2.8 | U | 23 | UJ |
| Aroclor 1221 | 3.8 | U | 7.3 | U | 5.2 | U | 6.3 | U | 8.5 | UJ | 5.7 | U | 2.6 | U | 2.4 | U | 5 | UJ | 4.5 | UJ | 15 | UJ |
| Aroclor 1232 | 6.1 | UJ | 12 | UJ | 8.3 | UJ | 6.3 | U | 10 | UJ | 11 | UJ | 4.1 | UJ | 3.9 | UJ | 7.5 | UJ | 6.8 | UJ | 18 | UJ |
| Aroclor 1242 | 3.8 | U | 7.3 | U | 5.2 | U | 6.3 | U | 8.5 | UJ | 5.7 | U | 2.6 | U | 2.4 | U | 5 | UJ | 5.7 | UJ | 29 | UJ |
| Aroclor 1248 | 3.8 | U | 7.3 | U | 5.2 | U | 6.3 | U | 4.2 | U | 5.7 | U | 2.6 | U | 2.4 | U | 5.5 | UJ | 2.8 | U | 7.3 | U |
| Aroclor 1254 | **7.3** | | **15** | | 5.2 | U | **11** | **J** | **6** | | **17** | | 2.6 | U | 2.4 | U | **12** | | **5.4** | | **27** | |
| Aroclor 1260 | **4.1** | | 7.3 | U | **6.9** | | 6.3 | U | 4.2 | U | **16** | | 2.6 | U | 2.4 | U | **10** | | 2.8 | U | **30** | |
| Aroclor 1262 | 3.8 | U | 7.3 | U | 6 | UJ | 6.3 | U | 4.2 | U | 12 | UJ | 2.6 | U | 2.4 | U | 8.7 | UJ | 2.8 | U | 23 | UJ |
| Aroclor 1268 | 3.8 | U | 7.3 | U | 5.2 | U | 6.3 | U | 4.2 | U | 5.7 | U | 2.6 | U | 2.4 | U | 3.1 | U | 2.8 | U | 7.3 | U |
| Total PCBs | **11.4** | | **15** | | **6.9** | | **11** | **J** | **6** | | **33** | | 2.6 | U | 2.4 | U | **22** | | **5.4** | | **57** | |

**Bolded** values indicate analyte detections.
U = The analyte was not detected at or above the reported sample quantitation limit.
J = The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte.
UJ = The analyte was not detected at or above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately measure the analyte.

Grain Size = Gravel (>2.00 mm), Sand (0.0625 to 2.00 mm), Silt (0.0039 to 0.0625 mm), Clay (<0.0039 mm), Fines (Silt + Clay).

Table B-2. Sediment Chemistry Results for South Lake Washington Sediments (ug/Kg dw, part per billion) continued.

| Site Name: | WA-34 | | WA-35 | | WA-36 | | WA-37 | | WA-38 | | WA-39 | | WA-40 | | WA-41 | | WA-42 | | WA-43 | | WA-44 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample No.: | 0902007-33 | | 0902007-34 | | 0902007-35 | | 0902007-36 | | 0902007-37 | | 0902007-38 | | 0902007-39 | | 0902007-40 | | 0902007-41 | | 0902007-42 | | 0902007-43 | |
| % Solids | 21.3 | | 19.6 | | 30 | | 44.6 | | 39.5 | | 26.1 | | 25.5 | | 15.3 | | 22.5 | | 34.4 | | 31.2 | |
| % TOC | 3.61 | | 3.7 | | 2.68 | | 1.21 | | 1.11 | | 2.91 | | 8.97 | | 4.41 | | 4.23 | | 3.79 | | 2.41 | |
| *Grain Size* | | | | | | | | | | | | | | | | | | | | | | |
| % Gravel | 0.00 | | 0.00 | | 0.00 | | 0.57 | | 0.58 | | 0.47 | | 0.13 | | 0.00 | | 0.00 | | 0.00 | | 3.89 | |
| % Sand | 57.4 | | 50.2 | | 74.4 | | 89.5 | | 92.8 | | 65.1 | | 62.6 | | 34.8 | | 66.8 | | 51.2 | | 72.8 | |
| % Silt | 39.4 | | 38.7 | | 22.1 | | 14.3 | | 11.9 | | 29.8 | | 42.9 | | 61.3 | | 26.2 | | 47.9 | | 28.8 | |
| % Clay | 3.48 | | 6.23 | | 2.94 | | 2.43 | | 2.84 | | 6.08 | | 3.51 | | 10.3 | | 4.4 | | 3.42 | | 4.51 | |
| % Fines | 42.9 | | 44.9 | | 25 | | 16.7 | | 14.7 | | 35.9 | | 46.4 | | 71.6 | | 30.6 | | 51.3 | | 33.3 | |
| *PCBs* | | | | | | | | | | | | | | | | | | | | | | |
| Aroclor 1016 | 5.7 | U | 7.5 | UJ | 4.1 | UJ | 2.7 | U | 3.1 | U | 4.7 | U | 9.7 | UJ | 8.1 | U | 11 | UJ | 3.6 | U | 8 | UJ |
| Aroclor 1221 | 5.7 | U | 6.2 | U | 4.1 | UJ | 2.7 | U | 3.1 | U | 4.7 | U | 9.7 | UJ | 36 | UJ | 8.8 | UJ | 25 | UJ | 13 | UJ |
| Aroclor 1232 | 5.7 | U | 12 | UJ | 6.6 | UJ | 3.3 | UJ | 3.1 | U | 4.7 | U | 9.7 | UJ | 9.7 | UJ | 11 | UJ | 23 | UJ | 11 | UJ |
| Aroclor 1242 | 5.7 | U | 12 | UJ | 4.1 | UJ | 3.3 | UJ | 3.1 | U | 4.7 | U | 14 | UJ | 8.1 | U | 5.5 | U | 5.8 | UJ | 8 | UJ |
| Aroclor 1248 | 5.7 | U | 6.2 | U | 4.1 | UJ | 2.7 | U | 3.1 | U | 4.7 | U | 19 | UJ | 8.1 | U | 5.5 | U | **10** | | 4 | U |
| Aroclor 1254 | **8.4** | | **13** | | **5.4** | **J** | **4.4** | | **3.3** | | **10** | | **27** | **J** | **20** | | **15** | | 31 | UJ | **9.2** | |
| Aroclor 1260 | **6.9** | | **9.5** | | 4.1 | UJ | 2.7 | U | 3.1 | U | **6.2** | | **11** | **J** | **14** | | **14** | | **21** | | **7.2** | |
| Aroclor 1262 | 5.7 | U | 7.2 | UJ | 4.1 | UJ | 2.7 | U | 3.1 | U | 4.7 | U | 16 | UJ | 8.1 | U | 11 | UJ | 17 | UJ | 5.7 | UJ |
| Aroclor 1268 | 5.7 | U | 6.2 | U | 4.1 | UJ | 2.7 | U | 3.1 | U | 4.7 | U | 4.9 | UJ | 8.1 | U | 5.5 | U | 4.3 | UJ | 4 | U |
| Total PCBs | **15.3** | | **23** | | **5.4** | **J** | **4.4** | | **3.3** | | **16** | | **38** | **J** | **34** | | **29** | | **31** | | **16.4** | |

**Bolded** values indicate analyte detections.
U = The analyte was not detected at or above the reported sample quantitation limit.
J = The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte.
UJ = The analyte was not detected at or above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately measure the analyte.

Grain Size = Gravel (>2.00 mm), Sand (0.0625 to 2.00 mm), Silt (0.0039 to 0.0625 mm), Clay (<0.0039 mm), Fines (Silt + Clay).

Table B-2. Sediment Chemistry Results for South Lake Washington Sediments (ug/Kg dw, part per billion) continued.

| Site Name: | WA-45 | | WA-46 | | WA-46 | | WA-47 | | WA-48 | | WA-49 | | WA-49 | | WA-50 | | WA-51 | | WA-52 | | WA-53 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Replicate | | | | | | | | Replicate | | | | | | | | | |
| Sample No.: | 0902007-44 | | 0902007-45 | | 0902007-54 | | 0902007-46 | | 0902007-47 | | 0902007-48 | | 0902007-53 | | 0902007-49 | | 0902007-50 | | 0902007-51 | | 0902007-52 | |
| % Solids | 16.9 | | 19.7 | | 20.2 | | 17.1 | | 27.7 | | 16.2 | | 17.5 | | 32.5 | | 38 | | 27.5 | | 44.5 | |
| % TOC | 3.16 | | 2.76 | | 2.74 | | 3.88 | | 2.93 | | 4.45 | | 4.14 | | 2.45 | | 2.5 | | 2.73 | | 2.38 | |
| *Grain Size* | | | | | | | | | | | | | | | | | | | | | | |
| % Gravel | 0.00 | | 0.00 | | 0.00 | | 0.00 | | 0.00 | | 0.00 | | 0.00 | | 0.00 | | 0.00 | | 0.00 | | 0.00 | |
| % Sand | 18.8 | | 15.1 | | 12.6 | | 46.9 | | 68.4 | | 34.9 | | 40.4 | | 7.59 | | 13.0 | | 17.7 | | 37.5 | |
| % Silt | 61.4 | | 76.7 | | 80.1 | | 54.7 | | 22.9 | | 61.3 | | 48.6 | | 81.6 | | 83.3 | | 72.6 | | 65.7 | |
| % Clay | 11.9 | | 12.2 | | 12.1 | | 8.35 | | 3.85 | | 9.92 | | 4.16 | | 7.31 | | 7.78 | | 8.52 | | 4.45 | |
| % Fines | 73.3 | | 88.9 | | 92.2 | | 63.1 | | 26.8 | | 71.2 | | 52.8 | | 88.9 | | 91.1 | | 81.1 | | 70.2 | |
| *PCBs* | | | | | | | | | | | | | | | | | | | | | | |
| Aroclor 1016 | 7.4 | U | 13 | UJ | 6.1 | U | 8.6 | UJ | 5.2 | UJ | 7.6 | UJ | 7 | UJ | 3.8 | UJ | 3.1 | U | 4.5 | U | 2.8 | U |
| Aroclor 1221 | 7.4 | U | 10 | UJ | 6.1 | U | 7.2 | UJ | 8.6 | UJ | 7.6 | UJ | 7 | UJ | 3.8 | UJ | 3.1 | U | 7.9 | UJ | 2.8 | U |
| Aroclor 1232 | 7.4 | U | 13 | UJ | 6.1 | U | 11 | UJ | 5.2 | UJ | 12 | UJ | 7 | UJ | 3.8 | UJ | 3.1 | U | 4.5 | U | 2.8 | U |
| Aroclor 1242 | 7.4 | U | 13 | UJ | 6.1 | U | 8.6 | UJ | 4.3 | UJ | 7.6 | UJ | 7 | UJ | 3.8 | UJ | 3.1 | U | 4.5 | U | 2.8 | U |
| Aroclor 1248 | 7.4 | U | 6.3 | U | 6.1 | U | 7.2 | UJ | 4.3 | UJ | 7.6 | UJ | 7 | UJ | 3.8 | UJ | 3.1 | U | 4.5 | U | 2.8 | U |
| Aroclor 1254 | **11** | **J** | 6.3 | U | 6.1 | U | 9.6 | UJ | **14** | **J** | **14** | **J** | **27** | **J** | 3.8 | UJ | 3.1 | U | 4.5 | U | 2.8 | U |
| Aroclor 1260 | 7.4 | U | 6.3 | U | 6.1 | U | 7.2 | UJ | 5.8 | UJ | **12** | **J** | **15** | **J** | 3.8 | UJ | 3.1 | U | 4.5 | U | 2.8 | U |
| Aroclor 1262 | 7.4 | U | 6.3 | U | 6.1 | U | 7.2 | UJ | 4.8 | UJ | 9.1 | UJ | 11 | UJ | 3.8 | UJ | 3.1 | U | 4.5 | U | 2.8 | U |
| Aroclor 1268 | 7.4 | U | 6.3 | U | 6.1 | U | 7.2 | UJ | 4.3 | UJ | 7.6 | UJ | 7 | UJ | 3.8 | UJ | 3.1 | U | 4.5 | U | 2.8 | U |
| Total PCBs | **11** | **J** | 6.3 | U | 6.1 | U | 9.6 | UJ | **14** | **J** | **26** | **J** | **42** | **J** | 3.8 | UJ | 3.1 | U | 4.5 | U | 2.8 | U |

**Bolded** values indicate analyte detections
U = The analyte was not detected at or above the reported sample quantitation limit.
J = The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte.
UJ = The analyte was not detected at or above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately measure the analyte.

Grain Size = Gravel (>2.00 mm), Sand (0.0625 to 2.00 mm), Silt (0.0039 to 0.0625 mm), Clay (<0.0039 mm), Fines (Silt + Clay).

Table B-3. Total PCB Congener Results for the South Lake Washington Sediment Core.

| Section (cm intervals) | Estimated Year | Total PCB Congeners[a] (ug/Kg dw) | TOC[b] (%) | Field ID | Sample # |
|---|---|---|---|---|---|
| 0-2 | 2007 | 22* | 3.29 | WAcore-01 | 0902007-56 |
| 2-3 | 2004 | 10.5 | 3.3 | WAcore-02 | 0902007-57 |
| 3-4 | 2002 | 10.4 | 3.22 | WAcore-03 | 0902007-58 |
| 4-5 | 2000 | 15.9 | 3.37 | WAcore-04 | 0902007-59 |
| 5-6 | 1997 | 20 | -- | WAcore-05 | 0902007-60 |
| 6-7 | -- | -- | -- | -- | -- |
| 7-8 | 1990 | 31.4 | 2.78 | WAcore-06 | 0902007-61 |
| 8-9 | -- | -- | -- | -- | -- |
| 9-10 | 1983 | 33.1 | 2.71 | WAcore-07 | 0902007-62 |
| 10-11 | -- | -- | -- | -- | -- |
| 11-12 | 1977 | 127.2 | 2.55 | WAcore-08 | 0902007-63 |
| 12-13 | -- | -- | -- | -- | -- |
| 13-14 | 1971 | 252 | -- | WAcore-09 | 0902007-64 |
| 14-15 | -- | -- | 2.51 | -- | -- |
| 15-16 | 1965 | 71.6 | -- | WAcore-10 | 0902007-65 |
| 16-17 | -- | -- | -- | -- | -- |
| 17-18 | -- | -- | -- | -- | -- |
| 18-19 | 1954 | 7.2 | -- | WAcore-11 | 0902007-66 |
| 19-20 | -- | -- | -- | -- | -- |
| 20-21 | 1945 | -- | 2.25 | -- | -- |
| 21-22 | 1941 | 2 U | -- | WAcore-12 | 0902007-67 |
| 22-23 | -- | -- | -- | -- | -- |
| 23-24 | -- | -- | -- | -- | -- |
| 24-25 | 1920 | 2 U | -- | WAcore-13 | 0902007-68 |
| to 37 cm | -- | -- | -- | -- | -- |

U = The analyte was not detected at or above the reported sample quantitation limit.
a = Results for individual congeners can be accessed through Ecology's EIM database under Study ID BERA0006.
b = Total organic carbon values taken from Furl et al. (2009) (EIM Study ID CFUR0004).
* = Result is the mean of laboratory duplicates.
-- = not analyzed.

# Appendix C. Data Quality

Table C-1. Precision of Laboratory Duplicates for PCB Aroclors (ug/Kg dw).

| Sample Type: | Laboratory Duplicate | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sample No.: | 0902007-55 | Dup | | 0902007-07 | Dup | | 0902007-20 | Dup | |
| Parameter | Result | Result | RPD | Result | Result | RPD | Result | Result | RPD |
| Aroclor 1254 | 15 | 24 | **46%** | 7.2 | 3.9 | **59%** | 11 | nd | nc |
| Aroclor 1260 | 6.8 | 9 | **28%** | nd | nd | nc | nd | nd | nc |
| Total PCBs | 21.8 | 33 | **41%** | 7.2 | 3.9 | **59%** | 11 | nd | nc |

Dup = duplicate.
RPD = relative percent difference.
nd = not detected.
nc = not calculated.

Table C-2. Precision of Laboratory Matrix Spikes for PCB Aroclors.

| Sample No.: | 0902007-02 | | | 0902007-22 | | | 0902007-54 | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | MS | MSD | RPD | MS | MSD | RPD | MS | MSD | RPD |
| PCB-1016 | 84 | 77 | **9%** | 66 | 70 | **6%** | 70 | 72 | **3%** |
| PCB-1260 | 77 | 69 | **11%** | 55 | 59 | **7%** | 68 | 69 | **1%** |

MS = matrix spike.
MSD = matrix spike duplicate.
RPD = relative percent difference.

Table C-3. Precision of Field Replicate (Split) Samples for TOC, Grain Size, and PCB Aroclors.

| Sample Type: | Field Replicate | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sample No.: | 0902007-21 | 0902007-55 | | 0902007-45 | 0902007-54 | | 0902007-48 | 0902007-53 | |
| Parameter | Result | Result | RPD | Result | Result | RPD | Result | Result | RPD |
| TOC (%) | 5.16 | 4.67 | **10%** | 2.76 | 2.74 | **1%** | 4.45 | 4.14 | **7%** |
| *Grain Size (%)* | | | | | | | | | |
| Gravel | 0.00 | 0.00 | **0%** | 0.00 | 0.00 | **0%** | 0.00 | 0.00 | **0%** |
| Sand | 70.2 | 64.0 | **9%** | 15.1 | 12.6 | **18%** | 15.1 | 12.6 | **18%** |
| Silt | 30.5 | 35.5 | **15%** | 76.7 | 80.1 | **4%** | 76.7 | 80.1 | **4%** |
| Clay | 4.77 | 5.32 | **11%** | 12.2 | 12.1 | **1%** | 12.2 | 12.1 | **1%** |
| *PCBs (ug/Kg dw)* | | | | | | | | | |
| Aroclor 1254 | 20 | 15 | **29%** | nd | nd | nc | 14 | 27 | **63%** |
| Aroclor 1260 | 6.3 | 6.8 | **8%** | nd | nd | nc | 12 | 15 | **22%** |
| Total PCBs | 26.3 | 21.8 | **19%** | nd | nd | nc | 26 | 42 | **47%** |

RPD = relative percent difference.
nd = not detected.    nc = not calculated.

Table C-4. Laboratory Duplicates for PCB Congener Results (ug/Kg dw).

| Sample Type: | Laboratory Duplicate | | | |
|---|---|---|---|---|
| Sample No.: | 0902007-56 | | | |
| Parameter | Result | | Result | RPD |
| PCB-089/090/101 | 2 | U | 2.6 | nc |
| PCB-093/095 | 2 | U | 2.2 | nc |
| PCB-106/118 | 2 | U | 3.5 | nc |
| PCB-110 | 2 | U | 5.1 | nc |
| PCB-138/163/164 | 2 | U | 3.9 | nc |
| PCB-139/149 | 2 | U | 4 | nc |
| PCB-153 | 2 | U | 3 | nc |
| PCB-180 | 2 | U | 3.4 | nc |
| Total PCBs | 2 | U | 27.7 | nc |

U = the analyte was not detected at or above the reported sample quantitation limit.
RPD = relative percent difference.
nc = not calculated.

Table C-5. Precision of Laboratory Triplicate Samples for TOC.

| Sample Type: | Laboratory Triplicate | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample No.: | 0902007-01 | Dup | Trip | | 0902007-21 | Dup | Trip | | 0902007-41 | Dup | Trip | |
| Parameter | Result | Result | Result | RSD | Result | Result | Result | RSD | Result | Result | Result | RSD |
| TOC (%) | 1.25 | 1.43 | 1.19 | **10%** | 5.16 | 4.72 | 4.67 | **6%** | 4.23 | 3.51 | 4.01 | **9%** |

Dup = duplicate.
Trip = triplicate.
RSD = relative standard deviation.

Table C-6. Precision of Laboratory Triplicate Samples for Grain Size.

| Sample Type: | Laboratory Triplicate | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample No.: | 0902007-10 | Dup | Trip | | 0902007-20 | Dup | Trip | | 0902007-50 | Dup | Trip | |
| Parameter | Result | Result | Result | RSD | Result | Result | Result | RSD | Result | Result | Result | RSD |
| Gravel (%) | 0.00 | 0.00 | 0.00 | **0%** | 0.00 | 0.00 | 0.00 | **0%** | 0.00 | 0.00 | 0.00 | **0%** |
| Sand (%) | 57.6 | 45.1 | 46.2 | **14%** | 48.8 | 50.2 | 35.9 | **18%** | 13.0 | 14.1 | 12.6 | **6%** |
| Silt (%) | 36.6 | 49.4 | 40.3 | **16%** | 46.4 | 53.0 | 56.6 | **10%** | 83.3 | 80.6 | 81.0 | **2%** |
| Clay (%) | 4.76 | 3.85 | 5.21 | **15%** | 8.4 | 7.06 | 8.80 | **11%** | 7.78 | 5.93 | 5.84 | **17%** |

Dup = duplicate.
Trip = triplicate.
RSD = relative standard deviation.

# Appendix D. Statistical Correlations for PCBs, TOC, and Fines

Table D-1. Pearson Correlation of PCBs and TOC.

| Pearson Correlation | TOC |
|---|---|
| PCB Correlation Coefficient | .492** |
| Significance (2-tailed) | .001 |
| Number | 42 |

** Correlation is significant at the 0.01 level.

Table D-2. Kendall's Tau and Spearman's Rho Correlations with PCBs and TOC.

| Kendall's Tau | TOC |
|---|---|
| PCB Correlation Coefficient | .441** |
| Significance (2-tailed) | .000 |
| Number | 42 |
| Spearman's Rho | TOC |
| PCB Correlation Coefficient | .624** |
| Significance (2-tailed) | .000 |
| Number | 42 |

** Correlation is significant at the 0.01 level

Table D-3. Pearson Correlation of PCB and Fines.

| Pearson Correlation | Fines |
|---|---|
| PCB Correlation Coefficient | .370** |
| Significance (2-tailed) | .016 |
| Number | 42 |

** Correlation is significant at the 0.05 level.

Table D-4. Kendall's Tau and Spearman's Rho Correlations with PCBs and Fines.

| Kendall's Tau | Fines |
|---|---|
| PCB Correlation Coefficient | .286* |
| Significance (2-tailed) | .008 |
| Number | 42 |
| **Spearman's Rho** | **Fines** |
| PCB Correlation Coefficient | .391** |
| Significance (2-tailed) | .011 |
| Number | 42 |

* Correlation is significant at the 0.01 level.
** Correlation is significant at the 0.05 level.

# Appendix E. Bioaccumulation Model Information

Northern pikeminnow was selected for the bioaccumulation model because it is a top predator and was one of two species measured with the highest concentrations of PCBs in Lake Washington. Multiple publications allowed for more accurate representation of the northern pikeminnow diet (McIntyre, 2004; Mazur, 2004).

The model was parameterized using water quality data from King County's monitoring database, literature-derived biological data, and sediment chemistry from the current 2009 study (Tables E-1, E-2 and E-3). Values were selected to represent average conditions, and default parameter values[5] were accepted where site-specific values were not requested in the model. To keep the modeling exercise focused, the food web model included organisms in the northern pikeminnow's food web but excluded other piscivores such as cutthroat trout and largemouth bass. The model was intended to provide context for the measured sediment concentrations with regard to PCB bioaccumulation but not to necessarily predict tissue PCB concentrations with high accuracy.

[5] These are parameters that have low site specificity

Table E-1. Dietary Assumptions for Northern Pikeminnow Food Web.

| | Sediment/detritus | Phytoplankton | Zooplankton (Daphnia) | Trichoptera | *Neomysis mercedis* | Chironomids | Amphipods | Stickleback | Juvenile sockeye | Longfin smelt | Adult prickly sculpin | Juvenile sculpin | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Zooplankton (Daphnia) | | 1.0 | | | | | | | | | | | Assumed |
| Trichoptera | 0.4 | 0.5 | 0.1 | | | | | | | | | | Mecom, 1972 |
| *Neomysis mercedis* | 0.2 | | 0.8 | | | | | | | | | | Murtaugh, 1981 |
| Chironomids | 1.0 | | | | | | | | | | | | Assumed |
| Amphipoda | 0.6 | 0.3 | 0.1 | | | | | | | | | | Felton et al., 2008; Summers et al., 1997 |
| Threespine stickleback | | | 0.5 | | | | 0.5 | | | | | | McIntyre, 2004 |
| Juvenile sockeye | 0.05 | | 0.9 | | | 0.05 | | | | | | | Hampton et al., 2006 |
| Longfin smelt | | | 0.25 | | 0.5 | | 0.25 | | | | | | Chigbu and Sibley, 1998 |
| Adult prickly sculpin | 0.1 | | | | | | 0.6 | | 0.1 | 0.1 | | 0.1 | Tabor et al., 2007 |
| Juvenile sculpin | 0.3 | | | | | | 0.6 | | | | | | Tabor et al., 2007 |
| Northern pikeminnow | | | 0.05 | 0.03 | | | 0.09 | 0.24 | 0.19 | 0.28 | 0.1 | | Brocksmith, 1999 |

Table E-2. Lipid and Body Mass Assumptions in Bioaccumulation Model.

| Organism modeled | % Lipid | Mean Mass (g) | References |
|---|---|---|---|
| Phytoplankton | 0.5 | 0.001 | Burkhard, 1998 |
| Trichoptera | 1.7 | 0.08 | Morrison et al., 1997; Russell et al., 1999 |
| Neomysis mercedis | 6 | 0.012 | Burkhard, 1998; Morrison et al., 1999 |
| Zooplankton (Daphnia) | 1.5 | 0.001 | Morrison et al., 1999 |
| Chironomids | 6 | 0.005 | Morrison et al., 1999 |
| Amphipoda | 2 | 0.01 | Morrison et al., 1997; Russell et al., 1999 |
| Stickleback | 6.4 | 4 | McIntyre, 2004 |
| Juvenile sockeye | 3.8 | 13 | McIntyre, 2004 |
| Longfin smelt | 10.2 | 5 | McIntyre, 2004 |
| Adult prickly sculpin | 1.2 | 22 | McIntyre, 2004 |
| Juvenile sculpin | 1.2 | 0.3 | McIntyre, 2004 |
| Northern pikeminnow | 7.1 | 907 | McIntyre, 2004 |

Table E-3. Water and Sediment Parameters.

| Parameter | Value | Units | Source |
|---|---|---|---|
| Mean Water Temperature | 12 | $^{O}C$ | King County monitoring data |
| Dissolved Organic Carbon Content (OCwat) | 2.98E-06 | kg/L | King County monitoring data |
| Particulate Organic Carbon Content (POC) | 3.58E-07 | kg/L | King County monitoring data |
| Concentration of Suspended Solids (Vss) | 3.60E-06 | kg/L | King County monitoring data |
| Sediment Organic Carbon Content (OCsed) | 3.29% | % | King County monitoring data |
| Mean Water Column Dissolved Oxygen Saturation | 84.20% | % | King County monitoring data |
| Dissolved Oxygen Content | 9.68 | mg $O_2$ / L | King County monitoring data |
| Density of Sediments and Suspended Solids | 1.5 | kg/L | Assumed default |
| Density of Sediment Organic Carbon (Docsed) | 0.9 | kg/L | Assumed default |
| PCB Kow | 6.7 | none | Weighted-average Kow of detected congeners in 0-10 cm core sample |

Using the mean sediment PCB concentration from the current study of 17.0 ug/kg dw, northern pikeminnow whole body tissue PCB concentrations are estimated to be 730 ug/kg ww. This is about 300 ug/kg ww less than the mean PCB concentration measured by King County and used as the basis for the interim Lake Washington fish advisory released by Washington Department of Health (DOH, 2004). This difference may reflect model error or an actual decrease in concentrations since 2004. Model performance was within a factor of 2 comparing observed with predicted PCB concentrations as shown in Figure E-1.

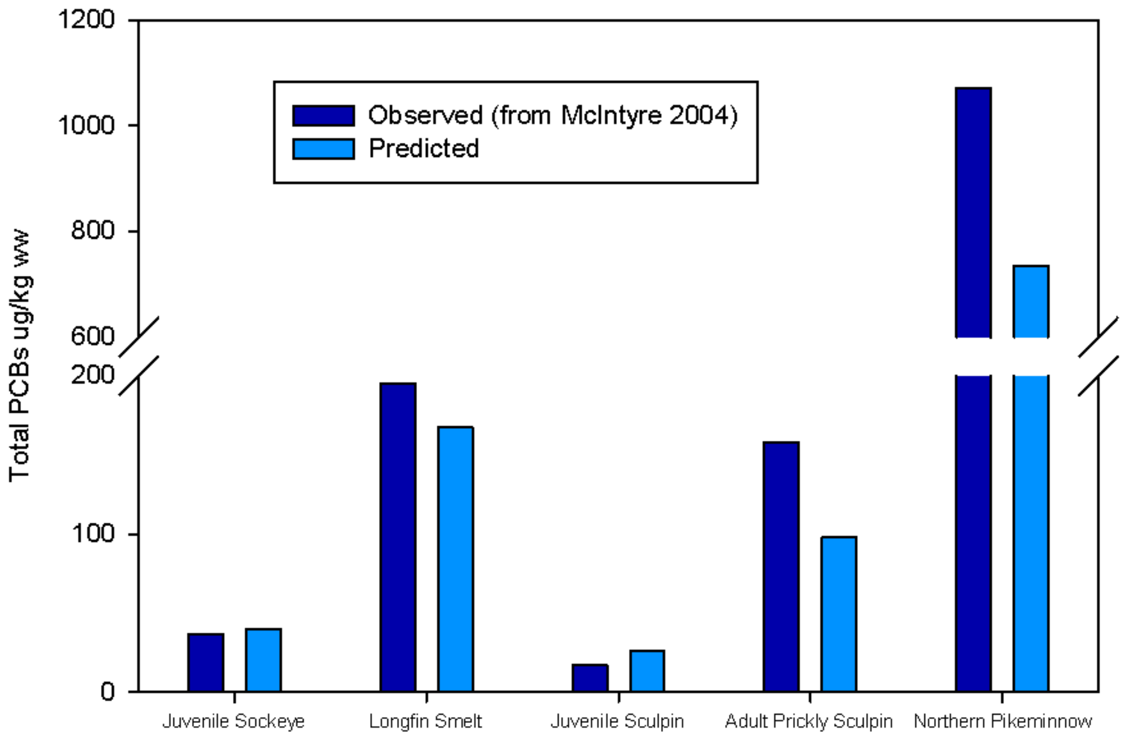


Figure E-1. Food Web Model Performance: Observed versus Predicted Concentrations.

# Appendix F. Laboratory Case Narratives

**Data Qualifier Codes used in this appendix**

| | | |
|---|---|---|
| U | - | The analyte was not detected at or above the reported result. |
| J | - | The analyte was positively identified. The associated numerical result is an estimate. |
| UJ | - | The analyte was not detected at or above the reported estimated result. |
| R (REJ) | - | The data are unusable for all purposes. |
| NAF | - | Not analyzed for. |
| N | - | For organic analytes there is evidence the analyte is present in this sample. |
| NJ | - | There is evidence that the analyte is present. The associated numerical result is an estimate. |
| NC | - | Not Calculated |
| E | - | The concentration exceeds the known calibration range. |
| G | - | Value is likely greater than result reported; result is an estimated minimum value. |
| **bold** | - | The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.) |

*This page is purposely left blank*

*Manchester Environmental Laboratory*
7411 Beach Dr E, Port Orchard, Washington 98366

**Case Narrative**

**June 11, 2009**

Subject: Lake Washington Sediments

Samples: 0902007-01 thru 0902007-55

Officer: Brandee Era-Miller

By: M.Mandjikov

# *PCB Analysis*

## Analytical Method(s)

Approximately 20 grams of each sediment sample was extracted with methylene chloride using automated Soxhlet extraction. The samples were then solvent exchanged into hexane, eluted through a micro Florisil® column with a 6% preserved diethyl ether/ 94% hexane solution, and extracted with tetrabutylammonium hydrogen sulfate (TBA) to remove sulfur.

Prior to analysis each extract was adjusted to 1 mL in iso-octane and treated with concentrated sulfuric acid.

These methods are modifications of EPA SW- 846 methods 3541, 3620, 3630, 3665, and 8082.

## Holding Times

All samples were prepared and analyzed within the method holding times.

## Calibration

All calibration and initial calibration verification are within the established quality control (QC) limits with the exception of the calibration curve for the first Aroclor 1016 peak from column B. The correlation of determination (COD) for the curve from this peak is less than the established QC limit of $\geq 0.990$. The CODs for the other four peaks used to calculate the mean result are within the control limits. Only laboratory control samples (LCS) and matrix spikes have been reported using this peak in the mean calculation. Therefore, no results have been qualified due to this low CC.

All reported results are bracketed with continuing calibration verification (CCV) standards within the control limits of 85% - 115% with the exception of sample 0902007-39. The CCVs bracketing this sample for column B exceed 115% recovery. Although the CCVs bracketing the sample for column A are acceptable, the interference on those Aroclor 1260 peaks caused too much uncertainty to report the mean. Instead, the mean result is reported as an estimate, “J”, from column B and may be biased high.

**Method Blanks**

There are no target analytes detected in the method blank.

**Surrogates**

Decachlorobiphenyl (DCB) and tetrachloro-m-xylene (TMX) were added to each sample and blank sample prior to extraction. Only DCB is used for control and reported in this PCB analysis. All DCB recoveries are within the established QC limits of 50% - 150% with the following exceptions.

The DCB recovery is below 50% for sample 0902007-39. The results for Aroclors 1254 and 1260 have been qualified as estimates, “J”, and may be biased low. All other Aroclor results for this sample have been reported at estimated reporting limits, “UJ”.

The DCB recovery for sample 0902007-35 is less than 50%. The result for Aroclor 1254 has been qualified as an estimate, “J”, and may be biased low. All other Aroclor results for this sample have been reported at estimated reporting limits, “UJ”.

**Duplicate Samples**

Samples 0902007-07, 0902007-20, and 0902007-55 were prepared in duplicate to assess the precision of this project. No analytes were detected in either the sample or duplicate sample of 0902007-07 and therefore no relative percent difference (RPD) was calculated.

The RPDs between the duplicate Aroclor 1254 results of samples 0902007-20 and 0902007-55 exceed Manchester Laboratories QC limits of ≤ 40% and the Quality Assurance Project Plan (QAPP)‘s QC limits of ≤ 50%. The Aroclor 1254 results for samples 0902007-20 and 0902007-55 have been qualified, “J”, as estimates.

**Matrix Spike and Matrix Spike Duplicate**

Samples 0902007-02, 0902007-22, and 0902007-54 were prepared in triplicate to assess the precision and accuracy of this project. Two of the replicates were spiked with Aroclors 1016 and 1260. All recoveries are within the acceptable QC limits of 50% - 150%.

All relative percent differences between the matrix spikes are less than 40%.

**Laboratory Control Sample**

A laboratory control sample (LCS) was prepared with each extraction batch by spiking a mixture of analytically clean Ottawa sand and Hydromatrix™ with Aroclor 1016 and Aroclor 1260. All recoveries are within the established QC limits of 50% - 150% recovery.

**Comments**

The following Aroclor 1254 results have been qualified, "J", as estimates due to relative standard deviations exceeding 40% between the peak results used to calculate the mean:

0902007- 06, 0902007-12, 0902007-14, 0902007-18, 0902007-20, 0902007-21, 0902007-25, 0902007-44, and 0902007-47.

The concentration of Aroclor 1254 in sample 0902007-42 cannot be quantified, although is probably present.  There are Aroclors 1248 and 1260 in the sample as well and they both share congeners with 1254.  1248 shares the early congeners and 1260 the late congeners.  Therefore, the apparent concentration of 1254 is a very high estimate from the contribution of these other Aroclors. Therefore, the Aroclor 1254 result is reported at an estimated reporting limit, "UJ".

The following results were raised and reported at estimated reporting limits, "UJ", due to interference.

Aroclor 1016:  0902007-26, 0902007-32, 0902007- 34, 0902007-39, 0902007-41, 0902007-43, 0902007-45 thru 0902007-47, and B09C171-DUP1.

Aroclor 1221:  0902007-03 thru 0902007-05, 0902007-13, 0902007-15, 0902007-16, 0902007-20, 0902007-21, 0902007-26, 0902007-30 thru 0902007-32, 0902007-39 thru 43, 0902007-45, 0902007-47, 0902007-51, 0902007-55, and B09C171-DUP1.

Aroclor 1232:  0902007-03 thru 0902007-14, 0902007-16, 0902007-17, 0902007-19 thru 22, 0902007-24, 0902007-26 thru 32, 0902007-34 thru 36, 0902007-39 thru 0902007-43, 0902007-45 thru 0902007-48, 0902007-55, B09C171-DUP1, and B09C173-DUP1.

Aroclor 1242:  0902007-05, 0902007-26, 0902007-30 thru 0902007-32, 0902007-34, 0902007-36, 0902007-39, 0902007-42, 0902007-43, 0902007-45, 0902007-46, and B09C171-DUP1.

Aroclor 1248:  0902007-30 and 0902007-39

Aroclor 1262: 0902007-01, 0902007-06, 0902007-08 thru 0902007-10, 0902007-24, 0902007-27, 0902007-30, 0902007-32, 0902007-34, 0902007-39, 0902007-41 thru 0902007-43, 0902007-47, 0902007-48, 0902007-53, 0902007-55, and B09C171-DUP1.

Aroclor 1268:  0902007-42

*This page is purposely left blank*

*Manchester Environmental Laboratory*
7411 Beach Drive East, Port Orchard Washington 98366

**August 10, 2009**

| | |
|---|---|
| Subject: | Lake Washington Sediment PCB |
| LIMS ID: | 0902007 |
| Samples: | 56 through 68 |
| Laboratory: | TestAmerica, Sacramento |
| Project Officer: | Brandee Era-Miller |
| By: | Karin Feddersen |

# *Data Review for PCB Congener Analysis*

## Summary

Data from these analyses were reviewed for qualitative and quantitative precision and bias following EPA method 1668A, revised August 20, 2003.

Samples were prepared and analyzed according to EPA method 1668A.

Results have been reported in nanograms per kilogram (ng/Kg), dry weight.

Several groups of congeners coelute. Each IUPAC # of the congeners in the coeleution is listed on the report, separated by a slash “/” with a single value. This reported value is a sum total of all the coeluting congeners.

The samples were diluted 5 times to overcome significant matrix interference. The reporting limit was high enough that it was not compromised. These results are marked with a “Y” in the “Re-analysis Flag” field.

## Holding Times

EPA method 1668A allows storage of samples for one year from the date of collection if stored in the dark at <4°C. Extraction and analysis took place within this time frame. The sample coolers were verified to be at <4 °C upon receipt at the contract lab.

## Method Blanks

The method blank is labeled:  G9D100000376B

No target compounds were detected in the laboratory blank.

## Calibration

The calibration standards were within 20% relative standard deviations (RSD) for all target analytes and 35% for all the labeled reference compounds (Internal Standards).

All calibration verification standard recoveries were within method limits of 70% to 130% for target analytes and 50% to 150% for the labeled reference compounds.

All the ion abundance ratios and relative retention times were within QC criteria.

## Internal Standard Recoveries

Recoveries for labeled compounds in these samples were all within QC limits of 15% to 150% for PCB-1L and PCB-3L, and 25% to 150% for all others, with several exceptions. These limits are consistent with the updates and revisions from 2003 to Method 1668A.

PCB-001, 002, and 003 were reported from the original undiluted analysis for all samples except 0902007-63 due to low recoveries of the labeled 13C-PCB-003.

Analytes that use the affected labeled compounds for quantification as in Table 2 of method 1668A are qualified with “J” for detected analytes and “UJ” for non-detects. Congeners that may have been biased high are flagged if the affected congener was not detected. Only PCB-194 in sample 0902007-63 was affected. This result was qualified as an estimate.

## Ion abundance ratios

Each congener reported as detected met the isotopic abundance ratio and retention time criteria for positive identification with the exception of one internal standard, which did not affect the results.

## Ongoing Precision and Recovery (OPR) or Laboratory Control Sample (LCS)

The OPR is labeled: G9D100000376C

Target analyte recoveries were within quality control limits of 50 to 150%.

Labeled compound recoveries were within quality control limits of 15% to 140% for PCB-1L and PCB-3L and 30 to 140% for all others with several exceptions which did not affect the results, since target analyte recoveries were within QC limits.

*Manchester Environmental Laboratory*
7411 Beach Dr E, Port Orchard, Washington 98366

**Case Narrative**

**March 20, 2009**

Subject: General Chemistry Lake Washington Sediments PCBs

Project No: 0902007

Officer: Brandee Era-Miller

By: Dean Momohara

**Summary**

The laboratory did not encounter any problems in the analyses of these samples. All sample results were reported without qualification.

All analyses requested were evaluated by established regulatory quality assurance guidelines.

**Methods**

The laboratory analyzed the samples by the following method: PSEP-TOC for total organic carbon (TOC).

**Sample Information**

The laboratory received the samples on 03/09/09. The temperature(s) of the coolers received were within the proper range of 0°C - 6°C. All samples were received in good condition and frozen. Sixty eight samples were received and assigned laboratory identification numbers 0902007-01 to 0902007-55.

**Holding Times**

The samples were frozen until they were processed. The laboratory performed all analyses within established EPA holding times.

**Calibration**

Instrument calibrations and calibration checks were performed in accordance with the appropriate method. All initial and continuing calibration checks were within control limits. The calibration correlation coefficients were within the acceptance range of 1.000 - 0.995. Oven temperatures were recorded before and after each analysis batch and were within acceptable limits.

**Method Blanks**

No analytically significant levels of analyte were detected in the method blanks associated with these samples.

**Matrix Spikes**

NA

**Replicates**

All duplicate relative standard deviations were within the acceptance range of 0% - 20%.

**Laboratory Control Samples**

All laboratory control sample recoveries were within the acceptance limits of 80% - 120%

Please call Dean Momohara at (360) 871-8808 to further discuss this project.

cc:  Project File

*Manchester Environmental Laboratory*
7411 Beach Drive East, Port Orchard, Washington 98366

*April 8, 2009*

| | |
|---|---|
| Subject: | Lake WA Sed PCBs |
| Samples: | 0902007-01 through 55 |
| Project ID: | 0902007 |
| Laboratory: | Columbia Analytical Services |
| Project Officer: | Brandee Era-Miller |
| By: | Karin Feddersen |

## Grain Size

### Comments

A % solids re-analysis was required for several samples. The moisture content was very high on samples 0902007-10 and 0902007-20. Not enough sample remained for a reanalysis of the % solids on these samples. Therefore, Columbia used the % solids values obtained by Manchester Laboratory for calculating results for samples 0902007-10 and 0902007-20.

### Analytical Methods

These samples were analyzed for Grain Size following Puget Sound Estuary Program protocols for Gravel, Sand, Silt, Clay determinations only.

### Holding Times

All samples were analyzed within the recommended holding time of 6 months days from collection.

### QC Samples

Triplicate analyses were performed on samples 0902007-10, 0902007-20 and 0902007-50.