PCBs, Dioxins, and Furans in Fish, Sediment, and Wastewater Treatment Plant Effluent from West Medical Lake

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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: West Medical Lake looking from south to north (photo by Randy Coots).

PCBs, Dioxins, and Furans in Fish, Sediment, and Wastewater Treatment Plant Effluent from West Medical Lake

by

Randy Coots and Casey Deligeannis

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

Waterbody Number: WA-43-9160

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Abstract

The Washington State Department of Ecology conducted a toxics study of West Medical Lake between February and October 2008. Six fish tissue, seven sediment, and four Medical Lake wastewater treatment plant (WWTP) effluent samples were collected. The toxics analyzed included polychlorinated biphenyls (PCBs), 2,3,7,8-tetrachlorodibenzodioxin (TCDD or dioxin), and other chlorinated dioxins and furans. Additional conventional parameters analyzed included lipids in fish tissue, total organic carbon and grain size in sediments, and total suspended solids and total organic carbon in WWTP effluent.

Total PCB concentrations in fish tissue were generally low compared to statewide levels. However the Environmental Protection Agency National Toxic Rule (NTR) human health criterion was still exceeded by a factor of 2 to 8. Tissue concentrations of dioxins/furans were low, and TCDD was not detected.

Total PCBs and dioxins/furans in sediment were below apparent effects thresholds for the protection of benthic infauna based on Washington State's proposed freshwater Sediment Quality Guidelines.

Total PCBs in WWTP effluent were low and below the NTR criterion for human health throughout the study period. In the April sample, TCDD was reported just above the reporting limit, exceeding the NTR criterion. The April results may be related to the WWTP upset in the de-nitrification system. No furans were reported above detection limits.

Recommendations include:

1. Consider changing the West Medical Lake 303(d) listing for TCDD from Category 5 (on the list) to Category 1 (meets standards) during the next water quality assessment (year 2012).
2. Re-analyze West Medical Lake rainbow trout in five years to assess levels of PCBs, dioxins, and furans.
3. Analyze PCBs, dioxins, and furans in rainbow trout at the time of planting to determine if there is contamination from hatchery sources prior to introduction to the West Medical Lake.

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- Steve Cooper, lead operator at the Medical Lake Wastewater Treatment Plant, was very helpful throughout the study especially with his historical knowledge and assistance with collecting samples.
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  - Chris Donley's knowledge of the lake and help with collecting fish was much appreciated.
  - Lucinda Morrow age dated the fish collected for the study.
- Washington State Department of Ecology staff:
  - Ken Merrill proposed and helped develop the study and also assisted in collecting sediment samples.
  - Karin Baldwin took over the project and was helpful in defining the final product.
  - Dale Norton and Art Johnson reviewed the document.
  - Joan LeTourneau and Cindy Cook prepared the final report.

Introduction

In 2002 the Washington State Toxic Monitoring Program (WSTMP) collected samples of rainbow trout from West Medical Lake. One composite of fillet from 10 fish was analyzed. Results from this sample were responsible for placing West Medical Lake on the 2004 303(d) list for total polychlorinated biphenyls (PCBs) [listing ID: 42173] and 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) [listing ID: 42381].

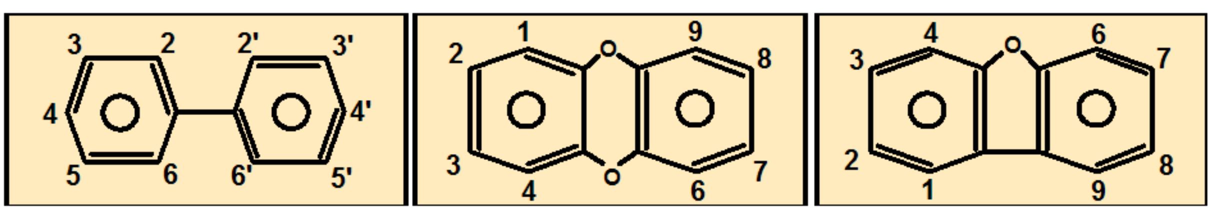
Since that time the 303(d) listing policy has changed resulting in using only the concentration of 2,3,7,8-TCDD. The WSTMP sample that justified the 303(d) listing in 2004 was based on 2,3,7,8-tetrachlorodibenzofuran (TCDF).

The federal Clean Water Act requires that waterbodies on the 303(d) list be cleaned up by pollution control programs or that a total maximum daily load (TMDL) be developed. A pollution-control program needs to address the sources of pollution and have a monitoring and enforcement component. A TMDL identifies pollution problems in the watershed and specifies how much pollution needs to be reduced or eliminated to achieve clean water. When developing a pollution-control program or a TMDL, Ecology will work with the local community and other relevant stakeholders to identify all actions that need to occur to address the sources of pollution. Monitoring to assess the effectiveness of those implementation actions will also be developed. That monitoring will be used to determine success or the next steps needed.

303(d) Parameters

PCBs, dioxins, and furans are similar in structure and are classes of organic chemicals that are persistent, bioaccumulative, and toxic. They can remain in the environment for many years and move between water, air, soil, and sediments. With the ability to move between these media, they threaten the food chain and can accumulate in animals and humans. Higher detection levels are typically reported from fish tissue and sediment (parts per billion) than water (parts per trillion or quadrillion) because of the hydrophobic nature of these contaminants.

Figure 1 shows the structure and numbering system of PCBs, dioxins, and furans. The numbered locations are chlorine bonding sites.



Polychlorinated biphenyls (PCBs) | Polychlorinated dibenzo-p-dioxin (PCDD) | Polychlorinated dibenzofuran (PCDF)

Figure 1. Structure and Numbering System of PCBs, Dioxins, and Furans.

PCBs

PCBs are synthetic organic compounds with no natural sources. PCBs enter the environment through their use and disposal. The commercial value of PCBs was based on their chemical stability and electrical insulating properties. Use largely focused around coolants and lubricants in transformers, capacitors, and other electrical equipment. Production of PCBs was banned by the Environmental Protection Agency (EPA) in 1979.

PCBs are normally analyzed as congeners or Aroclors. Congeners are individual chlorinated biphenyl molecules that are identified by the number and location of chlorine atoms around the biphenyl rings joined by a carbon-carbon bond. There are a total of 209 PCB congeners possible. Aroclors are commercial mixtures of congeners based on the application and the desired properties. Detection limits are higher for Aroclor analysis.

Dioxins and Furans

Dioxins and furans are the common names associated with polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF). These compounds are formed as an unintended byproduct during combustion of organic compounds in the presence of chloride. Sources are waste incinerators, pulp mills, industrial processes, and even backyard burn barrels. There is no commercial or domestic use for dioxins or furans. Ecological effects can occur because of their persistence and ability to biomagnify in the food chain.

There are a total of 210 possible dioxin and furan congeners. Like PCBs they are identified by the number and location of chlorine atoms around the biphenyl rings, but in this case, joined by oxygen atoms (Figure 1). The highest toxicity is associated with the 17 co-planar congeners (7 dioxin and 10 furan) that have chlorine atoms located in the 2,3,7, and 8 positions. The most toxic of these congeners is 2,3,7,8-TCDD.

Watershed Description

West Medical Lake is located within the Upper Crab Creek watershed in eastern Washington about 15 miles southwest of Spokane. Forming the western boundary of the City of Medical Lake, the shoreline surrounding the lake is largely natural. A picnic area is located on the east shore, and a large public access with boat rentals and docks is on the south shore (Figure 2). The land surrounding the lake is owned by the state with no near-shore residential development. The drainage area to West Medical Lake is mainly agriculture with wheat fields the major land use.

West Medical Lake is one of the few lakes in Washington State receiving a National Pollutant Discharge Elimination System (NPDES) permitted discharge. Nutrient levels in the lake are elevated, classifying it as “highly eutrophic”. It may be one of the most enriched lakes in the state (Smith et al., 2000). Aquatic plants are thick in most places. Zooplankton support one of the most productive trout fisheries in the state (Donley, 2008). The Washington Department of

Fish and Wildlife (WDFW) have operated aerators in the past to maintain adequate dissolved oxygen levels and prevent fish kills. West Medical Lake is not normally used for primary contact recreation.

Draining a relatively small basin of about 1.8 miles^2, West Medical Lake has approximately 4 miles of shoreline, a surface area of 220 acres, and an average depth of 22 feet. With no natural inflows or outflows, the hydraulic residence time of this seepage lake is very long, estimated at about 29 years (Willms and Pelletier, 1992).

The arid climate of eastern Washington averages about 80 degrees from June through August. From December through February the average high is about 35 degrees. Annual precipitation is slightly more than 16 inches per year. Elevation of West Medical Lake is 2,420 feet above sea level.

Water Quality Standards and Guidelines

Fish Tissue and WWTP Effluent

In 1992, EPA established water quality criteria for the protection of human health from the adverse effects of priority pollutants. The criteria are called the National Toxics Rule (NTR) (40 CFR 131). The Clean Water Act required states without sufficient human health criteria for priority pollutants to adopt the National Toxics Rule. Human health criteria are calculated for an increased lifetime cancer risk of one in one million (10^{-6}) from the consumption of fish or water. Water quality criteria for the toxic parameters addressed in this study for West Medical Lake are shown below in Table 1.

Table 1. Washington State Water Quality Criteria for PCBs and 2,3,7,8-TCDD.

Chemical	Criteria for Protection of Aquatic Life - Freshwater		Criteria for Protection of Human Health		
	Acute (ng/L)	Chronic (ng/L)	Water and Fish Consumption (ng/L)	Fish Consumption (ng/L)	Fish Tissue
Total PCBs	2,000	14	0.17	0.17	5.3 *u*g/Kg
2,3,7,8-TCDD			0.000013	0.000014	0.065 ng/Kg

Sediments

Washington State has not formally adopted regulatory numeric standards or EPA criteria for chemical contaminants in freshwater sediments. Instead, recommended numerical Freshwater Sediment Quality Values (FSQVs) are used as guidelines. The FSQVs are intended for the protection of sediment-dwelling organisms from toxic effects of chemical contaminants.

Avocet (2003) has developed FSQVs as both Sediment Quality Standards (SQS) and Cleanup Screening Levels (CSL) for Washington State. The SQS are concentration thresholds below which biological effects are not expected. The CSL estimates the concentration below which minor adverse effects can occur and above which more significant effects are likely.

The FSQVs presented below in Table 2 have been developed from field studies and laboratory data. The most recent SQS guidelines for use in Washington State are shown for PCBs (Avocet, 2003) and TCDD (Cubbage et al., 1997). In addition, two other sets of FSQVs for total PCBs from the state of Florida (Florida DEP, 2003) and Ontario, Canada (Jaagumagi and Persaud, 1999) are shown. The Florida value is consensus-based and developed using five threshold effect guidelines developed by MacDonald et al. (2000). Differences in proposed guideline values lie in the different chemical mixtures present in sediments and the biological effect from them.

Table 2. Recommended Numerical Guidelines for Total PCBs and TCDD in Freshwater Sediments from Washington State, Ontario, and Florida.

Guideline		Reference
Total PCBs (*ug*/Kg, dw)		
Washington State [1]	62	Avocet, 2003
Ontario [2]	70	Jaagumagi and Persaud, 1999
Florida [3]	60	Florida DEP, 2003
TCDD (ng/Kg, dw)		
Washington State [4]	8.8	Cubbage et al., 1997

[1] - Reported as LAET, "Lowest Apparent Effects Threshold".
[2] - Reported as LEL, "Lowest Effect Level".
[3] - Reported as TEC, Consensus-based "Threshold Effects Concentration".
[4] - Reported as AET, "Apparent Effects Threshold".

Potential Sources of Contamination

Historical Discharges

Historically, two facilities discharged treated wastewater directly to West Medical Lake:

- Eastern State Hospital and Lakeland Village, operated by the Washington State Department of Social and Health Services.
- Pine Lodge Corrections Center for Women, operated by the Washington State Department of Corrections.

Discharges from these state facilities were rerouted in October 2000 and connected to the City of Medical Lake's new wastewater treatment plant (WWTP).

Permit Holders

Under the NPDES Waste Discharge Permit and Reclaimed Water Permit No. WA-0021148, the City of Medical Lake is authorized to discharge reclaimed water to West Medical Lake. The effective date of the permit was June 1, 2005 and expiration was April 27, 2010. A new permit is expected by the end of summer 2010.

The current NPDES permit does not address discharge limits for total PCBs or TCDD. The design flow is for an average maximum discharge per month of 1.85 million gallons per day (mgd).

The Medical Lake WWTP provides tertiary treatment by activated sludge, coagulation, and filtration. Following tertiary treatment, effluent is divided and discharged to a tributary of Deep Creek and West Medical Lake. The West Medical Lake portion is discharged by way of a manifold extending from the eastern shoreline at the historical WWTP to almost the center of the lake as reclaimed water for augmentation and maintenance of the lake's water level. During the dry season WWTP discharge to West Medical Lake averages between 0.4 and 0.5 mgd, and during the wet season the discharge averages between 0.7 and 1.0 mgd (Cooper, 2007).

Nonpoint Sources

There are a number of possible nonpoint (diffuse) sources of PCBs and TCDD to West Medical Lake. Air deposition is a likely contributor from both local and global sources. Entering the air during manufacture, use, and disposal, airborne contaminants such as PCBs and TCDD can travel long distances before being deposited back to the earth's surface.

Waste burning of materials containing PCBs and TCDD contributes to the airborne pool of contaminants available as fallout to land and water surfaces. Uncontrolled combustion is thought to be a major source of PCBs and TCDD today. Anything from backyard trash burning to industrial incinerators can be considered a potential source. A recent EPA study (EPA, 2006) found that residential burning of household trash is a leading source of dioxins to the air. Agricultural burning and forest fires are also thought to contribute dioxins.

Because of the persistent nature of PCBs, contaminant levels found in West Medical Lake today could be partly a result of past improper or illegal handling as well as disposal of transformers and other electrical equipment containing PCBs.

Stormwater runoff from Eastern State Hospital, Lakeland Village, other facilities within the drainage area, and agricultural lands may also be playing a role as a source of PCBs and TCDD to the lake. In addition to direct deposition from the air, PCBs and TCDD can bind to soils and wash off to surface waters during storm events.

Lake sediments may also play a role as an internal source of pollutants to the food chain. Historical discharges to the lake from the state facilities, in addition to other ambient sources, have likely contributed to sediment contamination.

Figure 2. Study Area.

Methods

Overview

This study was conducted under the guidance of the Quality Assurance Project Plan (QAPP) entitled *West Medical Lake Total PCBs and Dioxin (2,3,7,8-TCDD) Total Maximum Daily Load* (Coots, 2008), which can be found at: www.ecy.wa.gov/pubs/0803104.pdf . Sampling locations for the study are shown below on Figure 3. Analytical methods, reporting limits, and sample preparation are presented in Table 3.

Study objectives included:

- Evaluating current levels of total PCBs and TCDD in fish tissue, sediment, and WWTP effluent.

- Providing the fish tissue data to the Washington State Department of Health to evaluate the need of a fish consumption advisory.

These objectives were met through characterizing the current levels of PCBs and TCDD in edible fish tissue and sediments from West Medical Lake. Seasonal loads of PCBs and TCDD were also monitored for the Medical Lake WWTP discharge to the lake.

The current West Medical Lake 303(d) listings for PCBs and TCDD are based on rainbow trout tissue, so they were targeted for collection and analysis. Rainbow trout are the dominant species in the lake. WDFW stocks the lake with 150,000 to 300,000 rainbow trout annually (Donley, 2008). The planting consists of catchable size fish, as well as some brood stock and triploids. Carry-over fish two or more years of age were targeted for collection.

The Washington State Department of Health was consulted during study development to ensure the number of fish targeted for collection would meet the needs of a fish consumption advisory evaluation.

Medical Lake WWTP loads of total PCBs and TCDD discharged during the 2008 study year were calculated from results reported for seasonal effluent samples and the flow rate from the WWTP at the time of sampling. Maximum loads for total PCBs and TCDD were also developed using the water quality criteria for each contaminant and sample time flows for the Medical Lake WWTP facility.

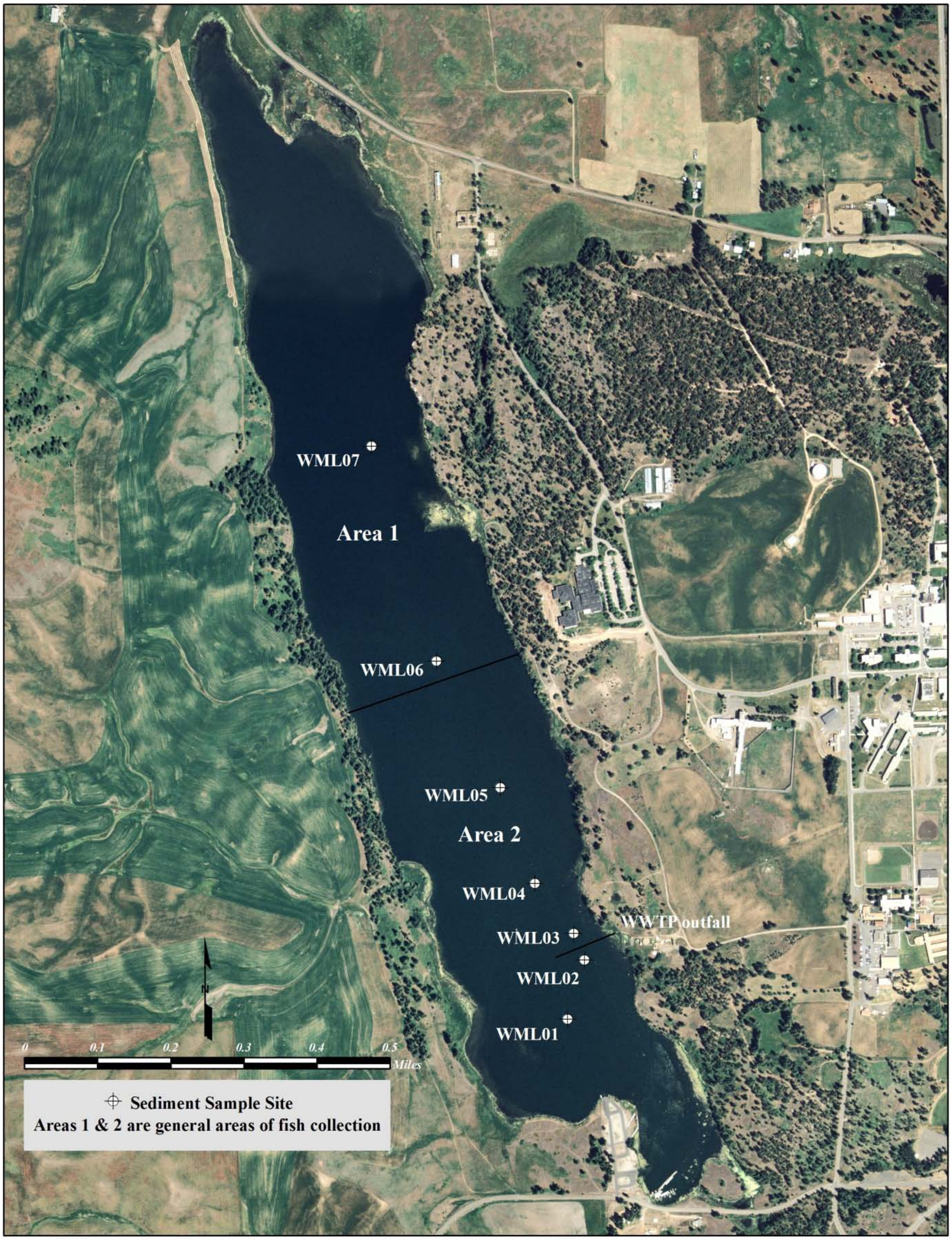


Figure 3. Sediment Collection Sites and Fish Collection Areas.

Table 3. Methods for Fish Tissue, Sediment, and WWTP Effluent Sample Analysis.

Analysis	Reporting Limit	Sample Preparation Method	Analytical Method
Fish Tissue			
PCB Aroclors	5 *ug*/kg, wet	EPA 3541	EPA 8082
Dioxins/Furans	0.07 ng/Kg, wet	Silica-gel if needed	EPA 1613B
Percent Lipids	0.10%	Extraction	EPA 1613 B
Sediment			
PCB Aroclors	5 *ug*/kg, dry	EPA 3541	EPA 8082
Dioxins/Furans	0.05 ng/Kg, dry	Silica-gel if needed	EPA 1613B
Total Organic Carbon	0.10%	Combustion/NDIR	PSEP-TOC
Grain Size	0.10%	Sieve and Pipette	PSEP-1986
Effluent/Water			
PCB Congeners	10 pg/L	EPA 1668A	EPA 1668A
Dioxins/Furans	1 pg/L	EPA 1613B	EPA 1613B
Total Organic Carbon	1 mg/L	NA	SM 5310B
Total Suspended Solids	1 mg/L	NA	SM 2540D

NDIR – non-dispersive infrared detector.
NA – not applicable.
PSEP-TOC – Puget Sound Estuary Program – Total Organic Carbon.
SM – Standard Methods.

Fish

WDFW biologists routinely collect fish from West Medical Lake so Ecology took the opportunity to coordinate fish sampling for the project. Fish were collected by gill net in April 2008. The two fish collection areas are shown on Figure 3. Biological information for the individual fish collected for the study is presented in the Appendix, Table B1.

The lake was divided into two areas based on its general configuration and location of the NPDES discharge: (1) North lake (Area 1) and (2) South lake (Area 2) where the WWTP discharge is located (Figure 3). Rainbow trout (*Oncorhynchus mykiss*) were collected from each area for analysis.

A total of six composite fish tissue samples were collected from the lake, three from each of two sampling areas. Two of the three composites from each area were from the year-one age class, hold-overs from the previous year. These composites were made of five fish each. The third composite from each area was of larger fish ranging in age from two to three years. The larger fish composite from the north area was made from four fish, while the south area composite was made from two fish.

Composite fish tissue samples were made from equal weight portions of individual fish. The samples were homogenized to a uniform color and consistency. The composites were divided into the appropriate sample containers for PCB aroclor equivalents, dioxins and furans, and lipid analysis.

Sediment

A survey of West Medical Lake surface sediments was conducted to establish baseline conditions for PCBs, dioxins, and furans. The spatial extent and levels of these pollutants in sediment were previously unknown. A total of seven sediment samples were collected during April 2008. Two samples were collected adjacent to the WWTP outfall, with the remainder as transect collected at increased distances from the outfall (Figure 3). Coordinates of sample locations and general descriptions of sediment grabs are included in Appendix B, Table B2.

Sediment samples were collected from a Wooldridge 16-foot aluminum jet sled using a 0.05 m^2 stainless-steel Ponar grab and hand-crank davit. Samples were composites made from three separate grabs. A grab sample was considered acceptable if it was not overfilled, overlying water was present but not overly turbid, the sediment surface appeared intact, and the grab reached the desired sediment depth. When the grab was considered acceptable, overlying water was siphoned off and sub-sampling was initiated. Equal volumes of the top 2-cm of each grab was used as the sample.

Each composite sample was homogenized to a uniform color and consistency using dedicated stainless-steel spoons and bowls. Debris on the surface or sediment contacting the sides of the Ponar grab was not retained. Composites were divided into the appropriate sample containers for PCB aroclor equivalents, dioxins and furans, total organic carbon (TOC), and grain size.

WWTP Effluent

Effluent samples from the Medical Lake WWTP were collected on four occasions: once each in February, April, July, and October of 2008. Collection locations for sampling were the same as for NPDES requirements, just prior to effluent discharge. The July and October samples were collected from a sample port on the effluent line entering the lake at Eastern State Hospital's remnant WWTP. The February and April samples were collected as final effluent from the WWTP disinfection chamber. A temporary upset in the WWTP de-nitrification system in February and the lake level peaking in April required all effluent to be discharged to Deep Creek, as required in the NPDES permit.

The WWTP samples were collected as composites of the final effluent. To avoid the possibility of contamination by automatic samplers, grab samples were hand composited. Effluent composites consisted of four grabs, two collected in the morning (8:00 AM) and two collected in the afternoon (4:00 PM), during two consecutive days. The composite samples were analyzed for PCB congeners, dioxins and furans, TOC, and total suspended solids. Flow data were obtained from WWTP records.

Quality Assurance

Ecology's Manchester Environmental Laboratory prepared quality assurance reviews for all chemical data. Data are reviewed for qualitative and quantitative accuracy following the EPA National Functional Guidelines for Organic Data Review. Data were evaluated for adherence to sample holding times, instrument calibration, results for process blanks, duplicate analysis, recovery of surrogates, labeled compounds and matrix spikes, and laboratory control samples analyses.

Overall, a review of the data quality control and quality assurance from laboratory case narratives indicates the data are usable as qualified by Manchester Laboratory (MEL, 2008). Most data met measurement quality objectives established in the Quality Assurance Project Plan (Coots, 2008).

MEL performed all analyses within recommended holding times.

Results reported from analysis of quality control samples for PCB Aroclors in fish tissue and sediment met established quality control limits. No target analytes were detected in laboratory blanks.

Due to weathering and metabolic breakdown, PCB Aroclor patterns can differ from the analytical reference standards used for identification. If the relative standard deviation (RSD) between peaks used to quantify Aroclors exceeds 40%, results are reported as estimates ("J"). All results for Aroclor 1254 and 1260 in fish tissue were "J" flagged as estimates.

Sediment samples 08144050 and 08144051 had recovery of the surrogate decachlorobiphenyl reported just below the 50-150% limit. Aroclors detected in these sediment samples were qualified as estimates ("J").

A number of PCBs, dioxins, and furans were positively identified in effluent below the lowest calibration standard. When this occurred, these results were qualified as estimates ("J"). Recoveries for target analytes in laboratory control samples, calibration standards, and labeled reference compounds were within method specified quality control limits.

A field transfer blank was analyzed for dioxins and furans. None of the seventeen 2,3,7,8-chlorine substituted congeners were detected.

Several PCB, dioxin, and furan congeners were detected in method blanks. When analytes were also detected in the sample at less than 10 times the blank level, the sample result was qualified as not detected at an estimated concentration ("UJ").

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Results and Discussion

Fish

Biological statistics for fish collected during the study can be found in Appendix B, Table B1. Information for fish weight, length, sex, age, and field and laboratory identification of samples is presented. Figure 3 shows the two general areas where fish were collected.

Rainbow trout were targeted for sampling because they are the dominant species in West Medical Lake, the basis of the 303(d) listings, and a popular sport fish. Results from the analysis of fillets are shown in the Appendix B, Table B3 for PCB Aroclors and Table B4 for dioxins and furans. Three composite samples from each of the two collection areas of the lake were analyzed. Two of the three composites were comprised of layover fish planted the previous year. The third composite was of larger fish made up of hatchery brood stock or triploids, both routinely planted by WDFW.

PCBs

Total PCB Aroclors in rainbow trout fillets were generally low, averaging 24 *u*g/Kg (parts per billion) wet weight and ranging from 12 to 44 *u*g/Kg for all samples. The NTR human health criterion for total PCBs is 5.3 *u*g/Kg which was exceeded by a factor of 2 to 8. Aroclor PCB-1254, the most common Aroclor reported in fish tissue, was detected in all samples. Only one other Aroclor was detected: PCB-1260 was found in the large fish composite from the south lake area (sample 08214015).

The two composites of larger fish (08214012 and 08214015) had roughly twice the total PCB concentration as the four composites of smaller fish. The mean total PCB concentration of the four composites of smaller fish was 16.5 *u*g/Kg, while the mean for the two composites of larger fish was 40 *u*g/Kg.

The total PCB results from rainbow trout samples collected for this 2008 study were compared to total PCB data from rainbow trout collected statewide from 1993 to 2008, by Ecology and EPA. These data are available from Ecology's Environmental Information Management (EIM) system. The database contains all data monitored by, or required by, Ecology or recipients of Ecology grants.

The EIM data represent total PCBs in rainbow trout fillet from 107 sites over 15 years. Only total PCB results reported above detection limits are presented. Figure 4 presents a cumulative frequency plot displaying data as percentiles. Units on the Y axis are micrograms per kilogram (*u*g/Kg – parts per billion) of total PCBs plotted on a logarithmic scale. Levels of total PCBs measured in West Medical Lake rainbow trout fall between the 23rd and 60th percentile for all rainbow trout collected between 1993 and 2008 in Washington State. Composites of the smaller fish fall between the 23rd and 45th percentiles, while composites of the larger fish (samples 08214012 and 08214015) were at the 56th and 60th percentiles.

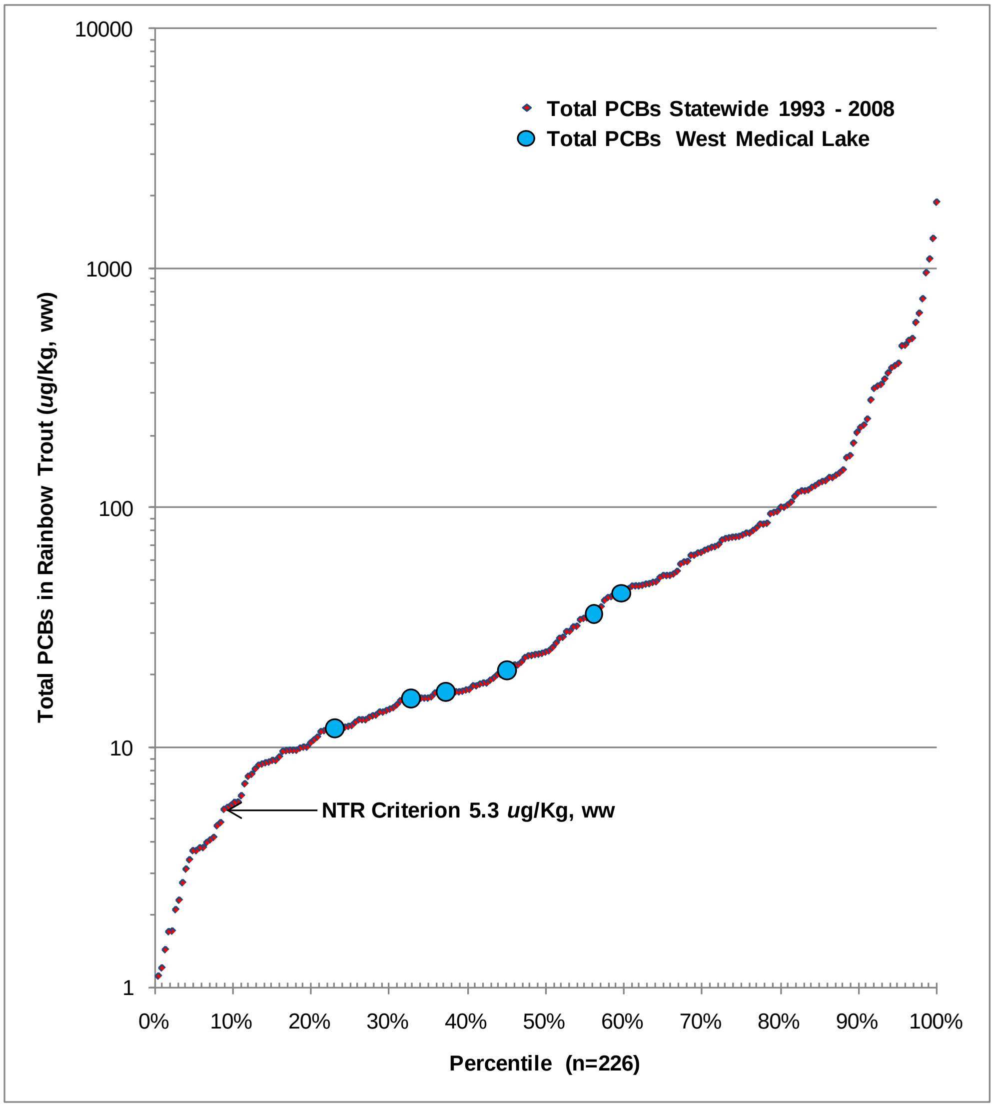

Figure 4. Cumulative Frequency Distribution of Total PCBs in Rainbow Trout Fillets Collected in 2008 from West Medical Lake Compared to Statewide Data for 1993-2008.

Fish food used at some WDFW hatcheries has recently been suspected of containing significant levels of PCBs and other persistent organic pollutants. A recent Ecology study reported some hatchery and planted fish contained concentrations of PCBs that may be above regulatory criteria (Serdar et al., 2006). West Medical Lake was not a part of the study, and it is not known if planted fish were affected by the contaminated fish food reported at some WDFW hatcheries (Donley, 2008).

Dioxins and Furans

The more highly chlorinated dioxins and furans were detected in the fish tissue samples. For dioxins, only the octa- congener was detected, while furans detected included the tetra-, penta-, hexa-, hepta-, and octa- congeners.

The levels of dioxins and furans were generally low in fish tissue, Appendix B (Table B4). TCDD the most toxic of the dioxins and furans, was not detected. The only dioxin congener reported above detection limits was octachlorodibenzo-p-dioxin (OCDD), the least toxic of the seven.

To assess the total potential toxicity of dioxins and furans in West Medical Lake fish tissue, toxic equivalent factors[1] (TEFs) were applied to study data (WHO, 2005). The toxicity of each detected congener is determined based on TEFs. Summing the TEF values for all the detected congeners gives a toxicity equivalent quotient (TEQ) which can be compared to TCDD criteria.

Figure 5 shows dioxin TEQs in the rainbow trout samples. TEQs averaged 0.090 ng/Kg (parts per trillion) wet weight, ranging from 0.039 to 0.130 ng/Kg. The NTR human health criterion for TCDD is 0.065 ng/Kg. The largest contributor to the TEQ was TCDF, which has a TEF of 0.1. The TCDF contribution to the total TEQ of each fish composite ranged from 71 to 93%.

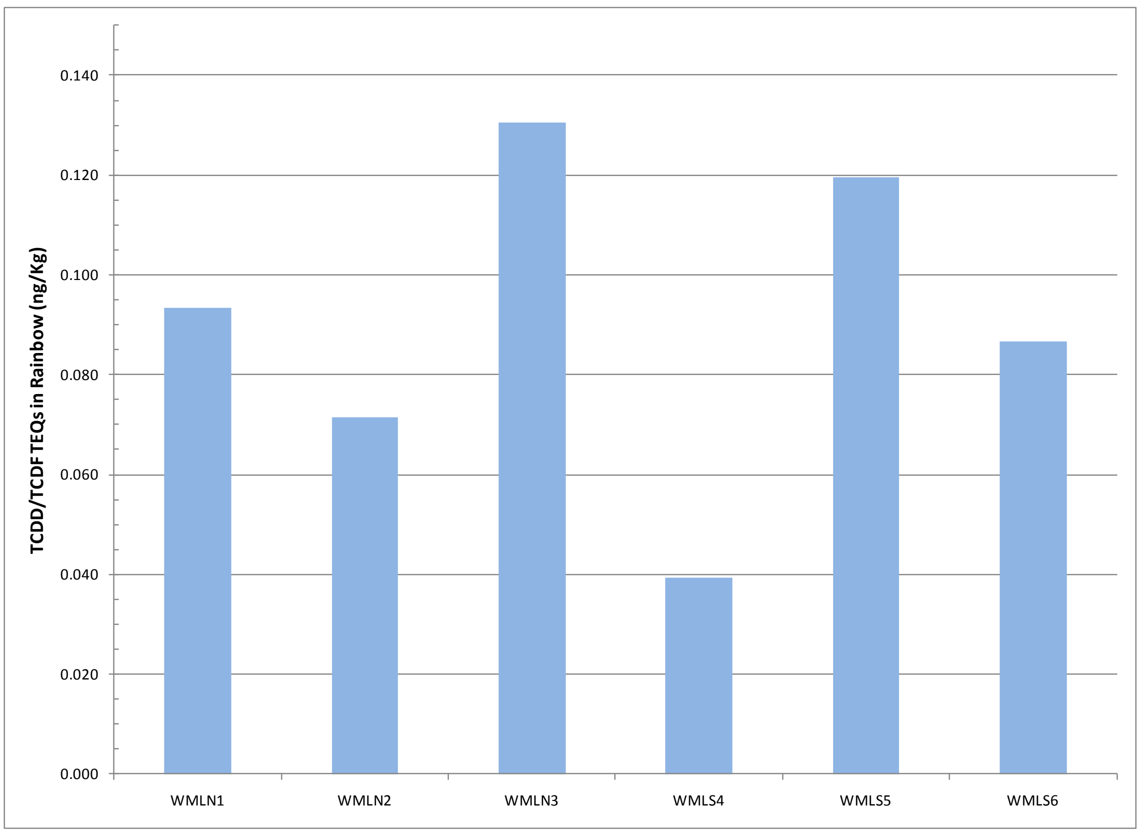

Figure 5. Dioxin TEQs in Rainbow Trout Tissue from West Medical Lake.

[1] 2,3,7,8-TCDD is the most toxic of the dioxin or furan congeners and is given a TEF of 1. Each of the other 16 dioxin/furan congeners of concern are given a TEF that is a decimal fraction of 1 based on the relative toxicity compared to 2,3,7,8-TCDD. TEFs are multiplied by the congener concentrations and summed to give a TEQ which can be compared to criteria for 2,3,7,8-TCDD.

Comparison to Previous Study

The WSTMP study results, responsible for the 303(d) listings for PCBs and dioxins/furans, (Seiders and Kinney, 2004) are compared to the results from this study in Table 4. The mean total PCBs in fish reported for this study was about a third less than the levels reported for the WSTMP fish. The composites of smaller fish from this study were lower in concentration, averaging less than one half the levels reported in the larger fish composites. The dioxin/furan TEQs were similar between studies, and no 2,3,7,8-TCDD was detected. Current 303(d) listing policy is to use the concentration of TCDD only, as the other dioxins and furans or TEQs are not addressed in the standards.

Table 4. Comparison of 2008 PCBs and PCDD/PCDF TEQs in fish tissue to WSTMP Data and NTR Criteria.

Study	Total PCBs (*ug*/Kg, ww)	PCDD/PCDF TEQ (ng/Kg, ww)	2,3,7,8-TCDD (ng/Kg, ww)	Lipids (percent)
Present study 2008	24.0[1]	0.090[1]	0.03 UJ	2.4[1]
Small/large fish composites from 2008	16.5/40.0[2]	0.081/0.11[2]	0.03 UJ/0.03 UJ	2.1/3.2[2]
WSTMP 2002	36.0	0.084	0.52 UJ[3]	2.4
NTR criteria	5.3	-	0.065	-

[1] = Study mean (six composites).
[2] = Mean of four small fish composites/mean of two large fish composites.
[3] UJ = Not detected at the estimated detection limit shown.

Two important factors that drive levels of toxics such as PCBs and TCDD in fish tissue are (1) biomagnification of contaminants through the food chain and (2) water column concentrations. Fish species, size, and age are also important in concentrating persistent toxic chemicals. The PCB and dioxin results reported by WSTMP, placing the rainbow trout on the 303(d) list, were from fish averaging 660 grams (Seiders and Kinney, 2004). The four composites of smaller fish collected for this study averaged only 164 grams, while the two composites of larger fish averaged 736 grams. These larger fish had similar concentrations of PCBs and dioxins as the samples collected by WSTMP that resulted in the 2008 303(d) listing.

West Medical Lake may not be the only source of PCBs and dioxins found in fish. As previously discussed, WDFW hatchery fish have been shown to have significant levels of PCBs from food (Serdar et al., 2006). In addition to the 150,000 to 300,000 catchable-sized rainbows stocked yearly, WDFW also plant brood stock and triploids. It is not known what levels of PCBs or TCDD were in the fish prior to planting or the residence time of the larger fish. So it is not clear what fraction of the PCB and TCDD load was acquired from the lake.

WDOH Human Health Evaluation

The Washington State Department of Health (WDOH) evaluates the human health risk of chemical contaminants in fish and issues advisories when levels of pollutants are a concern. WDOH conducted a Consumption Advisory Assessment of West Medical Lake rainbow trout collected during the 2008 study for total PCBs and TCDD. The assessment was completed in April 2009.

WDOH concluded that, "No restrictions are necessary due to either PCB or dioxin/furan levels in West Medical Lake rainbow trout. Recommended meal consumption rates are based in part on contaminant levels but also incorporate other factors such as background concentrations in rainbow trout or other species in Washington State, levels of contaminants in other foods, nutritional and cultural benefits. Rainbow trout from West Medical Lake would be a good choice for anglers" (McBride, 2009).

This consumption assessment is specifically for rainbow trout from West Medical Lake. Other species of fish that reside in the lake could have different levels or types of contaminants.

Fishery Management

WDFW applied the pesticide, rotenone, to West Medical Lake in October 2009 with the goal of restoring the lake to a trout fishery. Removal of competing populations of undesirable fish allows the WDFW to stock the lake with fry at almost a tenth the cost of planting catchable-sized trout. The beneficial effects are expected to last for six to eight years.

Tench, pumpkinseed sunfish, and possibly gold fish were targeted for removal. These exotic species were illegally planted in West Medical Lake. Following the rotenone treatment, the dead fish were not removed from the lake.

The fish community that this study reports results for no longer exists. Additional sampling would be required to determine current levels of PCBs or dioxins/furans in West Medical Lake fish.

Between March and May of 2010, the lake was replanted with over 160,000 rainbow trout. Four size classes of fish made up the plant: 125,000 fry at about 100 per pound; 35,000 catchable at about five per pound; 1650 triploids at about one and a half pound each; and 600 broodstock at about three pounds each.

Sediment

Surface sediments were collected from seven locations within West Medical Lake along a north to south transect (Figure 3). Two samples bracketed the WWTP outfall, with the remainder collected at increasing distances from the outfall. The sample coordinates, relative location within the lake, water depth at the collection site, and sediment description are presented in Table B2 in Appendix B. The complete set of results for PCBs, dioxins and furans, TOC, and percent fines from West Medical Lake sediments can be found in Tables B5 and B6.

West Medical Lake has been reported as one of the most enriched lakes in the state (Smith et al., 2000). Levels of TOC in surface sediments were high, averaging 6.9% and ranged from 6.1% to 8.0%. Field logs consistently noted sediment grabs had a black color, pudding-like texture, and the odor of hydrogen sulfide (Table B2). The most recent Washington State sediment quality guideline for TOC (Avocet, 2003) recommends TOC no greater than 9.8%.

Grain size results are presented in Figure 6. Particle distribution from site to site was fairly uniform. Samples were comprised largely of fines ranging from 66.4% to 97.2% (fines consist of silts and clays - particle sizes < 62.5 microns). Only the most southern sample (WML01) reported fines less than 75%.

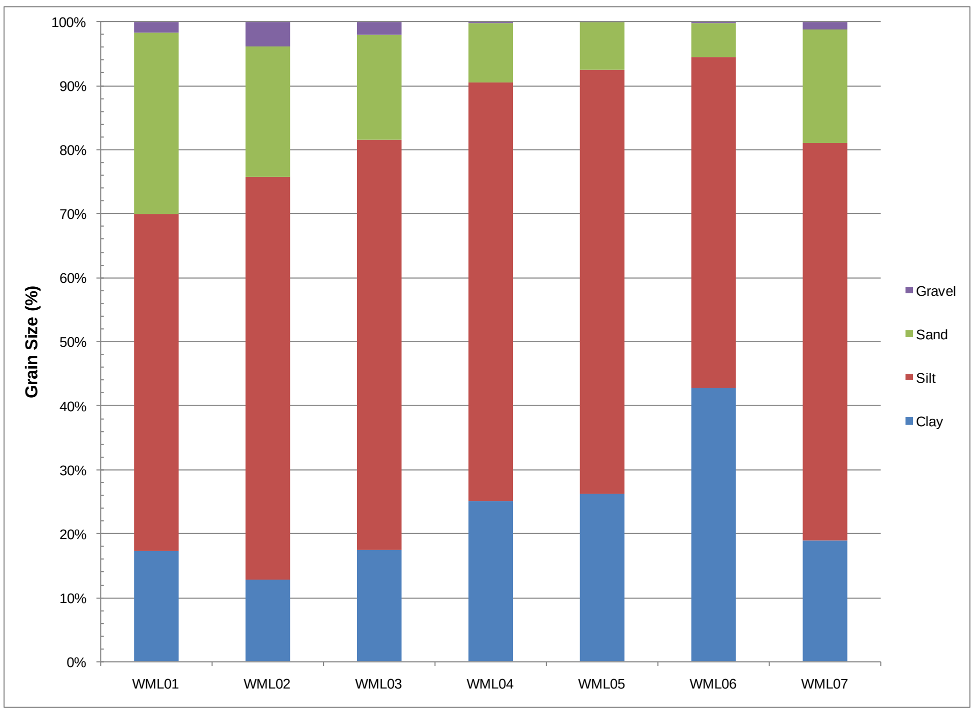

Figure 6. Grain Size Distribution of West Medical Lake Sediments.

PCBs

Sediment PCBs were analyzed as Aroclors. The most frequently detected Aroclors in sediment are PCB-1254 and PCB-1260. In this study only PCB-1254 was detected, in all samples. Levels of PCB-1254 were fairly low, ranging from 9.0 to 19 *ug*/Kg dry weight (dw) and averaging 14 *ug*/Kg dw (Table B5).

PCB levels were similar in sediment collected throughout the lake. Only small differences were found between samples collected adjacent to the WWTP outfall and samples from other sites. The maximum concentration reported from all samples was only twice the minimum. The highest level of PCB-1254 was reported from WML07, the northern most sample site (Figures 7 and 3). This site represented the farthest sample point from the WWTP discharge, suggesting the possibility there may be a source of PCBs entering the north lake area. These results also show WWTP effluent is not creating a PCB hot spot in the area adjacent to the outfall.

The lowest AET for total PCBs in the recommended freshwater sediment quality values for use in Washington State is 62 *ug*/Kg, dw (Avocet, 2003). The total PCB levels found in West Medical Lake's surface sediments average less than a fourth of the AET. This suggests a low probability of harm from PCBs to sediment-dwelling organisms in the top 2 cm of sediments.

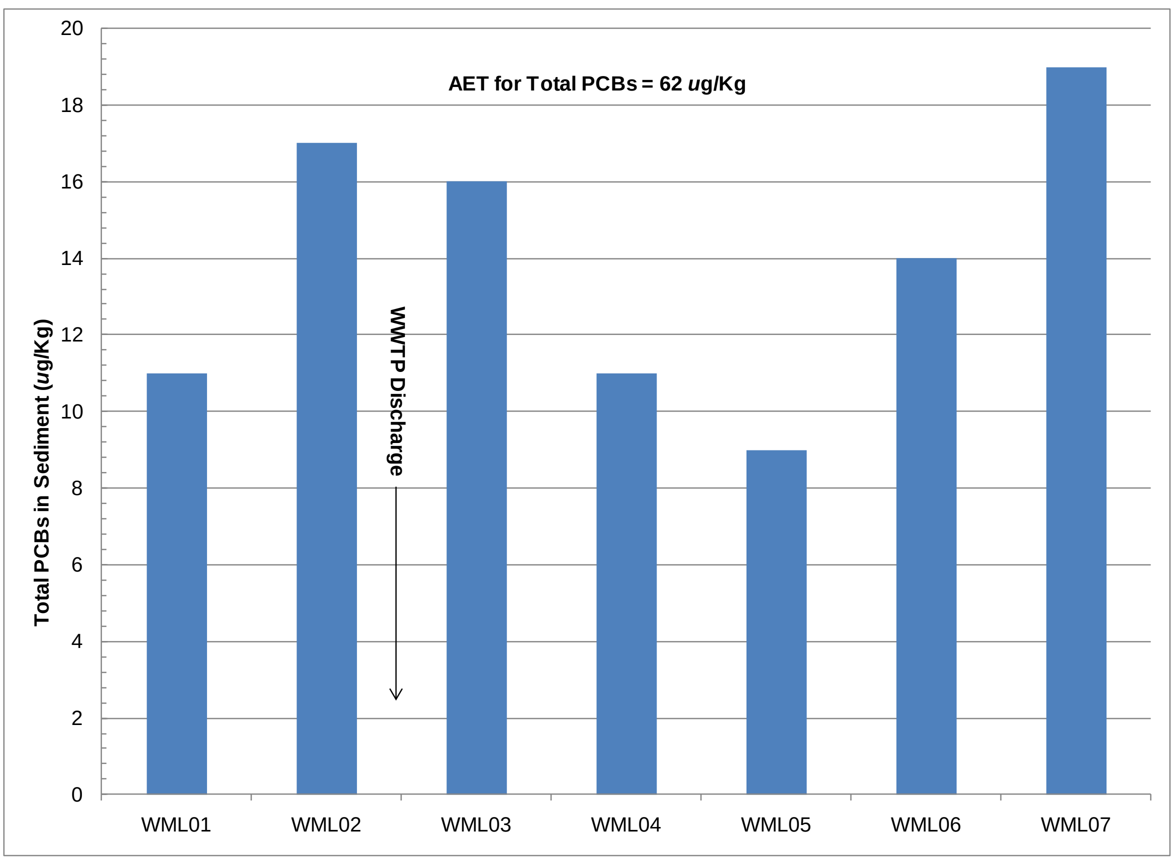

Figure 7. Total PCBs in West Medical Lake Sediments.

At times predictable relationships are identified between results from high-cost analysis for organic analytes and low-cost conventional parameters such as TOC or percent fines. For West Medical Lake, sediment PCBs were found to be only moderately correlated to TOC (r^2 = 0.61) and poorly correlated to percent fines (r^2 = -0.19).

Dioxins and Furans

Concentrations of dioxins and furans in sediment were generally low (Figure 8 and Table B6). 2,3,7,8-TCDD was reported above detection in all samples with a mean of 0.46 ng/Kg dw and ranging from 0.29 to 0.76 ng/Kg. The most recent freshwater sediment quality guideline for 2,3,7,8-TCDD, based on the AET for benthic infauna, is 8.8 ng/Kg dw (Cubbage et al., 1997). Levels of 2,3,7,8-TCDD reported for this study averaged more than an order of magnitude below the guideline concentration. Sediment TEQs ranged from 2.9 to 5.2 ng/Kg and averaged 4.2 ng/Kg, suggesting a low probability of causing harm to sediment-dwelling organisms.

Tetra- to octa-chlorinated dioxins and furans were detected in sediments. The highest concentrations of dioxins were reported in the more chlorinated homologs of the hepta- and octa- groups. The average 2,3,7,8-TCDD contribution to the total TEQ was 11%, and ranged from 8 to 15% (Figure 8). For furans, homologs from the tetra-, hepta- and octa-chlorinated groups were reported having the highest concentrations. The percent contribution of the seven 2,3,7,8-chlorine-substituted PCDDs and ten 2,3,7,8-chlorine-substituted PCDFs to the total TEQ was generally consistent, being about 60% and 40%, respectively (Table B6).

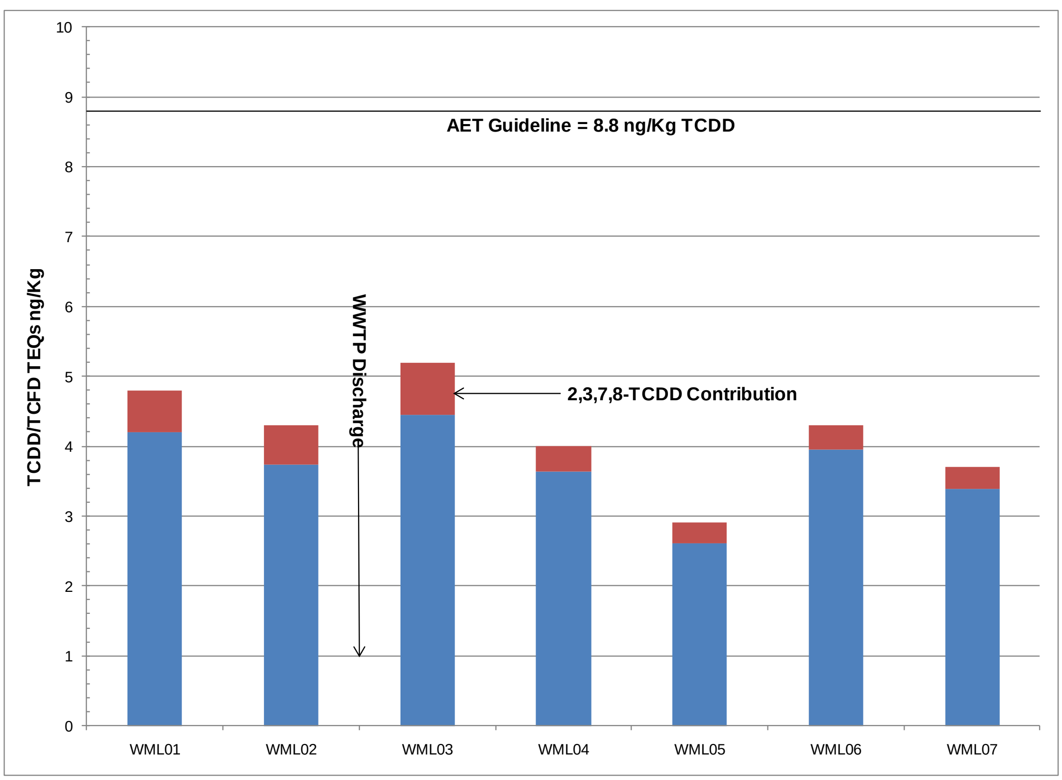

Figure 8. Dioxin TEQs in West Medical Lake Sediments.

WWTP Effluent

Discharge

During 2008 the Medical Lake WWTP discharge ranged between 0.334 and 1.303 million gallons per day (mgd). Flows for the January through June period were variable, ranging between 0.395 and 1.303 mgd. Discharge exceeded 1.0 mgd for a brief period from February 29 to March 17, averaging 1.13 mgd. July through December discharge was more stable, ranging from 0.334 to 0.503 mgd.

The discharge fluctuated seasonally (Figure 9). Influent volumes often increase in the winter and spring, caused by inflow and infiltration from water entering the collection system through joints, breaks, or cracks. Improper domestic connections like roof or foundation drains are other sources that can increase influent flows to the WWTP during winter and spring.

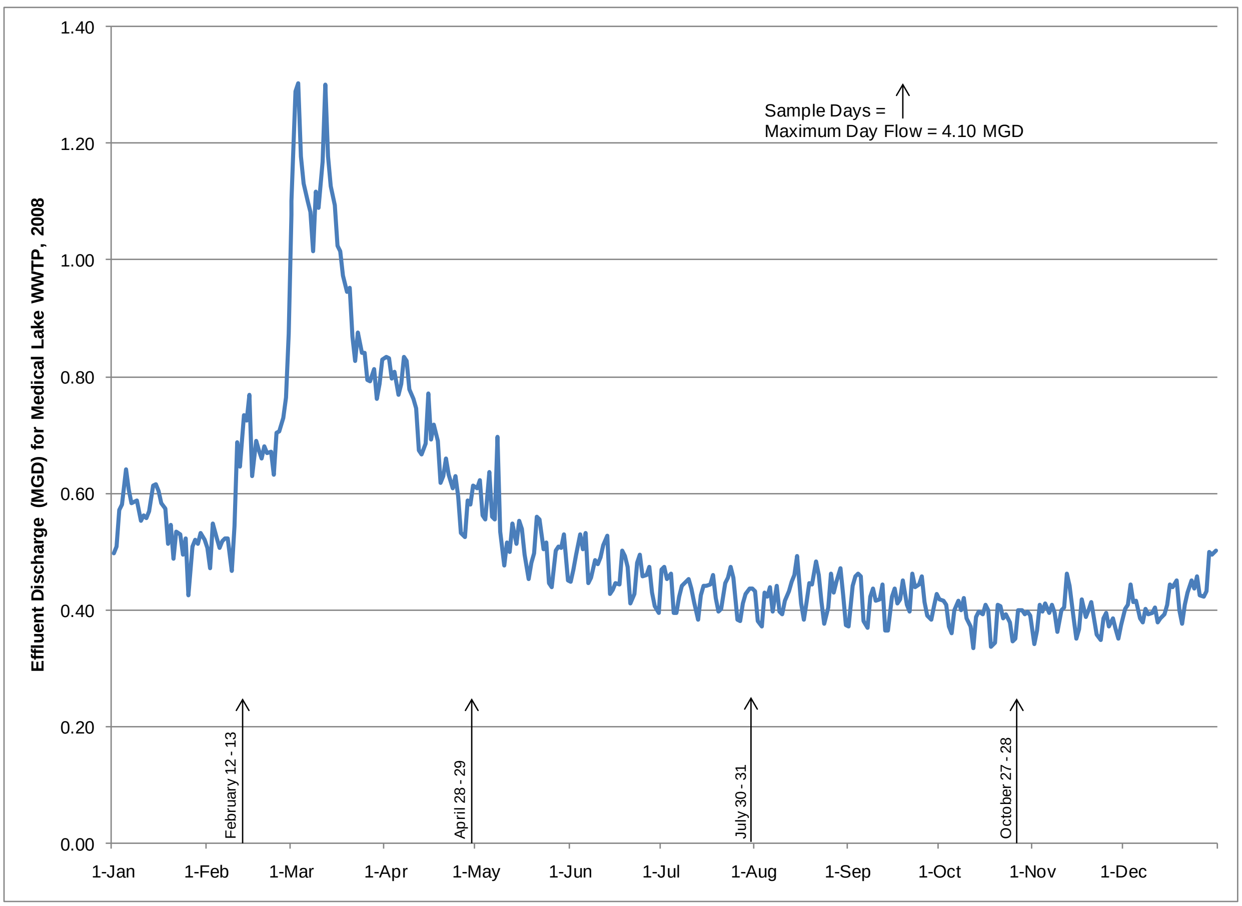

Figure 9. Daily Effluent Discharge from Medical Lake WWTP, 2008.

The Medical Lake NPDES permit (No. WA-0021148) requires effluent to be discharged to three possible locations. The primary outfall is to an intermittent unnamed tributary to Deep Creek. Throughout the year, effluent is discharged down the Deep Creek tributary with a NPDES permit required minimum of 0.10 mgd. The other two discharge locations are Use Area #1, West Medical Lake, for lake level augmentation, and Use Area #2, the City of Medical Lake reclaimed water system uses, such as landscape irrigation. During 2008 the City used reclaimed water between May 8 and October 13, averaging 0.012 mgd.

West Medical Lake has no natural surface inputs or outflows. Evaporation and seepage through the lake bottom or side walls accounts for the majority of lake water loss. Water levels are maintained by receiving effluent as reclaimed water from the Medical Lake WWTP. Effluent is discharged through a manifold located at the remnant Eastern State Hospital WWTP located on the eastern shore (Figure 2). The discharge limit is based on the lake stage. When the lake level reaches the defined maximum, all effluent is discharged to the Deep Creek tributary.

Table B7 in Appendix B presents information on effluent collection times, dates, and locations where samples were collected, in addition to results for TOC and TSS. Results for PCB congeners are shown in Figure 10, and results for dioxins/furans are in Tables B8 and B9.

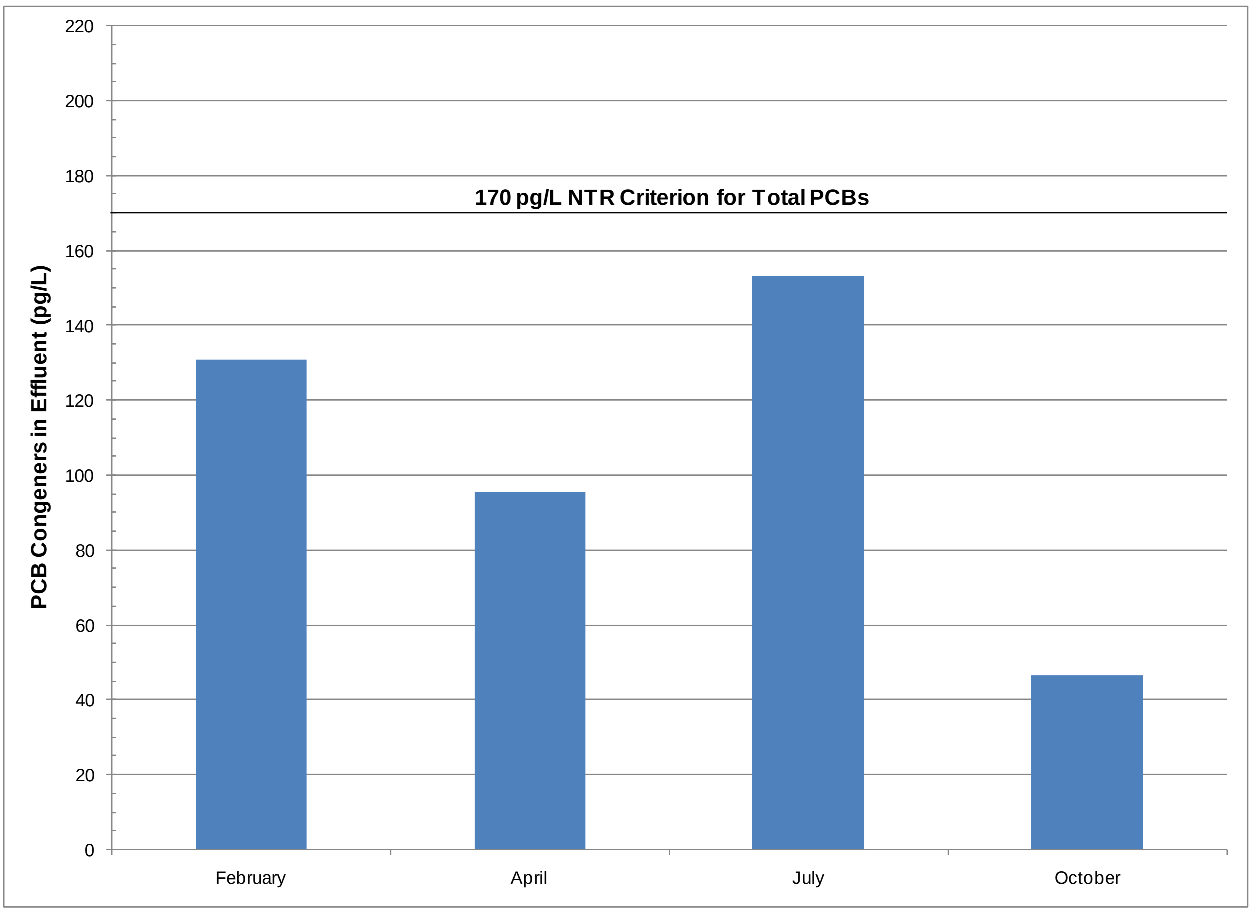

Figure 10. Total PCBs in Medical Lake WWTP Effluent.

PCBs

Table B8 summarizes the results for the PCB homolog groups. Di-, tri-, tetra-, penta-, and hexa-chlorinated homolog groups were detected in effluent samples. Total PCBs averaged 106 pg/L and ranged from 46.6 to 153 pg/L (parts per quadrillion) throughout 2008. This is below the 170 pg/L NTR human health criterion for total PCBs in water. The highest concentration was reported for the sample collected in July, while the lowest concentration was from October. There was no obvious seasonal trend.

Table 5 summarizes the PCB data that have been reported for eastern Washington WWTP effluents since 2001. Concentrations found in seasonal effluent samples from the Medical Lake WWTP are low compared to other WWTPs from areas that include agriculture and urban environments such as the Palouse, Walla Walla, Spokane, and Yakima.

Table 5. Summary of PCB Data for Eastern Washington WWTP Effluents.
(pg/L, parts per quadrillion; mean values)

Receiving Water/ WWTP	Year	N=	Total PCBs	Reference
Palouse River				
Pullman	2007-08	3	1400	Lubliner (2009)
Colfax	2007-08	3	330	
Albion	2007-08	1	1500	
Walla Walla River				
Walla Walla	2002-03	4	790	Johnson et al. (2004)
	2006-07	3	380	
College Place	2002-03	4	1300	Lubliner (2007)
	2006-07	3	300	
Spokane River				
Spokane	2001	2	1800	Golding (2002)
Liberty Lake	2001	2	1700	
Yakima River 18 facility mean	2007-08	72	580	Johnson et al. (2010)
West Medical Lake Medical Lake	2008	4	106	Present study

Dioxins and Furans

Few dioxins and no furans were reported above detection limits (Appendix B, Table B9). The sample collected in April had 2,3,7,8-TCDD reported at an estimated concentration of 0.56 pg/L (parts per quadrillion), just above the 0.50 pg/L reporting limit. This is about 43 times the 0.013 pg/L NTR human health criterion for 2,3,7,8-TCDD. Currently analytical capabilities are not able to reach the 2,3,7,8-TCDD NTR human health criterion. For this study the 2,3,7,8-TCDD reporting limit was 0.50 pg/L or about 38 times the NTR criterion. The large difference between the NTR criterion for 2,3,7,8-TCDD of 0.013 pg/L and the reporting limit of 0.50 pg/L suggests the possibility dioxins could be a concern.

During December 2007 through April 2008, the Medical Lake WWTP suffered an upset in their de-nitrification system. As a result this treatment process was taken off-line. The detection of 2,3,7,8-TCDD in effluent may be related to the upset. The de-nitrification system did not return to normal function until ambient temperatures started increasing in the spring when it was put back on-line.

The only other dioxin compound detected in effluent was OCDD at an estimated concentration of 3.03 pg/L. OCDD is the least toxic of the dioxin congeners, with a TEF of 0.0003 (OCDD TEQ = 0.00091 pg/L).

PCB and TCDD Loads

Chapter 173-201A WAC specifies inflows to West Medical Lake must meet water quality criteria at the point of discharge. This is particularly important to West Medical Lake, a seepage lake without the benefit of a clean natural inflow or outflow to shorten residence time, estimated at 29 years (Willms and Pelletier, 1992).

Water quality criteria are based on the concentration of a contaminant, expressed as a unit measure per volume of water: for example, micrograms per liter (*u*g/L). Determining a contaminant load removes the effects of dilution which can fluctuate throughout the year. Loads are calculated and expressed as a unit measure over a period of time: for example, milligrams per day (mg/day).

During the December and April sample events, all effluent from the WWTP was discharged to the Deep Creek tributary, averaging 0.638 mgd. For the July and October sample events, effluent was split with portions going to both West Medical Lake and the Deep Creek tributary. Total WWTP discharge averaged 0.412 mgd for the July and October periods, with 0.268 mgd going to West Medical Lake and 0.143 mgd to the Deep Creek tributary.

Table 6 presents calculated loads based on concentrations reported for samples collected during the study and effluent flows at the time of sampling. Loads discharged to West Medical Lake and the Deep Creek tributary are shown separately, along with allowable maximums based on the NTR human health criterion and total effluent discharge.

Table 6. Total PCB Loads Discharged and Allowable Loads from the Medical Lake WWTP.

Sample Date – 2007-08	Effluent Discharge to Deep Crk (mgd)	Effluent Discharge to WML[1] (mgd)	Total PCB Congeners in Effluent (pg/L)	Total PCB Load to Deep Crk (mg/day)	Total PCB Load to WML (mg/day)	Total PCB Load Discharged (mg/day)	Total Allowable PCB Load (mg/day)[2]	Percent of Allowable Load
Dec 12-13	0.691	0	131	0.343	0	0.343	0.445	77.1
Apr 28-29	0.584	0	95.3	0.211	0	0.211	0.376	56.1
Jul 30-31	0.120	0.304	153	0.0695	0.176	0.246	0.273	90.1
Oct 27-28	0.167	0.233	46.6	0.0295	0.0411	0.0706	0.257	27.5

[1] - West Medical Lake.
[2] - Allowable load is the WWTP flow rate at the time of sampling and the NTR criterion for total PCBs (170 pg/L).

The percent of total PCBs discharged compared to maximum allowable loads for the sample events ranged from 27.5 to 90.1%. The December sample period discharged the largest total PCB load (0.343 mg/day), and the October event discharged the smallest (0.0706 mg/day).

Only in the April sample was 2,3,7,8-TCDD detected. The maximum allowable load of 2,3,7,8-TCDD based on WWTP discharge at the time of sampling and the human health criterion was 0.029 *u*g/day. The 2,3,7,8-TCDD load discharged to the Deep Creek tributary during April was 1.24 *u*g/day. As previously discussed, sampling occurred during a WWTP upset and this upset is likely related to the sampling results.

Conclusions and Recommendations

Conclusions

The 303(d) listing for total PCBs in edible tissue of West Medical Lake fish should be retained based on data from this 2008 study. The NTR human health criterion for total PCBs was exceeded by a factor of 2 to 8. Although dioxins and furans were also detected, the current policy is to list for TCDD exceedances only. Fish tissue samples from this study did not have TCDD levels above detection limits. On this basis, West Medical Lake no longer qualifies for a 303(d) listing under Category 5 for TCDD.

Based on the WDOH assessment, no fish consumption restrictions are necessary due to either PCBs or dioxin/furan levels. Rainbow trout were found to be a good choice for anglers.

Levels of PCBs, dioxins, and furans in sediment were generally low and below recommended effects thresholds for benthic infauna. It does not appear the WWTP discharge has created a toxic hotspot adjacent to the outfall. The highest PCBs reported in sediments were from a northern site farthest away from the outfall, suggesting a source in the northern area of the lake.

Effluent from the Medical Lake WWTP show total PCBs were low and within the NTR human health criterion. Dioxins and furans were generally not detected except for the sample collected in April when TCDD and OCDD were present just above the limit of detection. From December 2007 through April 2008, the WWTP suffered a process upset in the de-nitrification system. Until warmer weather returned, the de-nitrification system did not return to normal operation and was off-line. These April results may be related to the WWTP upset in the de-nitrification system.

Recommendations

The results of this study support the following recommendations.

- The current West Medical Lake 303(d) listing for 2,3,7,8-TCDD in rainbow trout tissue should be revisited in the 2012 listing cycle for proper category placement based on this study's data.

- West Medical Lake rainbow trout should be analyzed for PCBs, dioxins, and furans in five years for comparison to this study's data.

- Catchable-sized rainbow trout planted by the Washington Department of Fish and Wildlife should be analyzed just prior to planting in West Medical Lake. This should be done to determine contaminant levels in the trout prior to planting in the lake.

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Appendices

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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.

Ambient: Background (environmental). Away from point sources of contamination.

Benthic infauna: Tiny sediment-dwelling invertebrates (e.g., aquatic insects, worms).

Bioaccumulative pollutants: Pollutants that 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.

Dioxins and furans: Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans.

Eutrophic: Nutrient rich and high in productivity resulting from human conditions such as fertilizer runoff and leaky septic systems.

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

National Pollutant Discharge Elimination System (NPDES): National program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

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

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.

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

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.

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

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

Following are acronyms and abbreviations used frequently in this report.

AET	Apparent effects thresholds
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
NPDES	(See Glossary above)
NTR	National Toxics Rule
OCDD	octachlorodibenzo-p-dioxin
OCDF	octachlorodibenzofuran
PCBs	polychlorinated biphenyls
PCDD	polychlorinated dibenzo-p-dioxins
PCDF	polychlorinated dibenzofurans
TCDD	2,3,7,8-tetrachlorodibenzodioxin
TEF	toxic equivalency factor
TEQ	toxic equivalent quotient (or concentration)
TMDL	(See Glossary above)
TOC	Total organic carbon

WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDOH	Washington State Department of Health
WSTMP	Washington State Toxics Monitoring Program
WWTP	Wastewater treatment plant

Units of Measurement

dw	dry weight
ft	feet
g	gram, a unit of mass
kg	kilograms, a unit of mass equal to 1,000 grams.
mg	milligrams
mgd	million gallons per day
mg/d	milligrams per day
mg/Kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mL	milliliters
ng/Kg	nanograms per kilogram (parts per trillion)
ng/L	nanograms per liter (parts per trillion)
pg/L	picograms per liter (parts per quadrillion)
ug/Kg	micrograms per kilogram (parts per billion)
µg/L	micrograms per liter (parts per billion)
ww	wet weight

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Appendix B. Study Tables

Table B1. Biological Data on West Medical Lake Rainbow Trout, April 11, 2008.

Site ID	Composite ID	Laboratory ID	Length (mm)	Weight (g)	Fillet Weight (g)	Sex[1] M, F, U	Age
RBT17	WMLN1	08214010	235	132	70	U	1
RBT15	WMLN1	08214010	263	173	87	U	1
RBT10	WMLN1	08214010	254	165	91	U	1
RBT9	WMLN1	08214010	261	158	97	U	ND
RBT1	WMLN1	08214010	281	194	105	U	ND
RBT6	WMLN2	08214011	262	163	85	U	ND
RBT7	WMLN2	08214011	253	162	97	U	1
RBT8	WMLN2	08214011	242	140	84	U	1
RBT12	WMLN2	08214011	276	198	114	M	2
RBT13	WMLN2	08214011	265	165	96	F	1
RBT33	WMLN3	08214012	383	702	183	F	2
RBT34	WMLN3	08214012	438	830	240	M	3
RBT35	WMLN3	08214012	385	701	170	F	2
RBT36	WMLN3	08214012	415	885	233	F	3
RBT21	WMLS4	08214013	253	181	94	U	ND
RBT23	WMLS4	08214013	235	137	80	U	ND
RBT24	WMLS4	08214013	269	178	106	U	ND
RBT27	WMLS4	08214013	250	154	89	U	1
RBT29	WMLS4	08214013	264	179	103	U	ND
RBT22	WMLS5	08214014	263	181	108	U	ND
RBT25	WMLS5	08214014	260	168	94	U	ND
RBT26	WMLS5	08214014	253	160	89	U	1
RBT28	WMLS5	08214014	245	169	96	U	ND
RBT30	WMLS5	08214014	233	130	68	U	ND
RBT31	WMLS6	08214015	375	600	276	F	2
RBT32	WMLS6	08214015	477	782	309	F	3

1 = Male, Female, Unable to determine visually.
ND = Not able to determine age.

Table B2. West Medical Lake Sediment Sample Coordinates and General Description.

Site ID	Latitude	Longitude	General Locations	Water Depth	Sediment Description
WML01	47.56538	-117.70521	Approx. 520' south of outfall	31 Feet	Fine black organic material - H_2S
WML02	47.56656	-117.70465	Approx. ≤ 100' south of outfall	27 Feet	Fine black organic material - H_2S
WML03	47.56709	-117.70494	Approx. ≤ 100' north of outfall	31 Feet	Fine black organic material – H_2S
WML04	47.56811	-117.70602	Approx. 550' north of outfall	32 Feet	Fine black organic material – H_2S (replicate site)
WML05	47.57003	-117.70694	Approx. 1300' north of outfall	33 Feet	Fine black organic material with brown surface
WML06	47.57257	-117.70867	Approx. 2300' north of outfall	33 Feet	Fine black organic material With brown surface
WML07	47.57687	-117.71035	Approx. 4000' north of outfall	30 Feet	Fine black organic material - H_2S

See Figure 3 for station locations.
H_2S = Hydrogen sulfide.

Table B3. PCB Aroclor Results from West Medical Lake Fish Tissue, April 2008 (*u*g/Kg, ww–ppb).

Site ID:	WMLN1	WMLN2	WMLN3	WMLS4	WMLS5	WMLS6	Human Health NTR (Total PCBs)
Sample ID (08):	214010	214011	214012	214013	214014	214015	
Lipids (%):	2.0	2.2	3.5	2.3	1.9	2.8	
PCB - 1016	2.7 U	2.8 U	2.7 U	2.8 U	2.7 U	2.7 U	5.3 *u*g/Kg
PCB - 1221	2.7 U	2.8 U	2.7 U	2.8 U	2.7 U	2.7 U	
PCB - 1232	2.7 U	2.8 U	2.7 U	2.8 U	2.7 U	2.7 U	
PCB - 1242	2.7 U	2.8 U	2.7 U	2.8 U	2.7 U	2.7 U	
PCB - 1248	4.4 UJ	3.3 UJ	5.5 UJ	2.8 U	3.3 UJ	4.4 UJ	
PCB - 1254	**12**	**21 J**	**36 J**	**16 J**	**17 J**	**30 J**	
PCB - 1260	2.7 U	4.4 UJ	11 UJ	3.3 UJ	3.3 UJ	**14 J**	
PCB - 1262	2.7 U	2.8 U	5.5 UJ	2.8 U	2.7 U	8.7 UJ	
PCB - 1268	2.7 U	2.8 U	2.7 U	2.8 U	2.7 U	2.7 U	
Total PCBs	**12**	**21 J**	**36 J**	**16 J**	**17 J**	**44 J**	

U = Not detected at the detection limit shown.
UJ = Not detected at the estimated detection limit shown.
J = The result is an estimate.
Bold = Analyte was detected.

Table B4. Dioxin and Furan Results from West Medical Lake Fish Tissue, April 2008 (ng/Kg, ww; pptr).

Site ID:	TEF[1]	WMLN1		WMLN2		WMLN3		WMLS4		WMLS5		WMLS6	
Sample ID (08):		214010		214011		214012		214013		214014		214015	
Parameter													
Lipids (%)		2.0		2.2		3.5		2.3		1.9		2.8	
Dioxins													
2,3,7,8-TCDD	1	0.03	UJ	0.03	UJ	0.03	UJ	0.03	UJ	0.03	UJ	0.03	UJ
1,2,3,7,8-PeCDD	1	0.033	UJ	0.033	UJ	0.033	UJ	0.033	UJ	0.033	UJ	0.033	UJ
1,2,3,4,7,8-HxCDD	0.1	0.1	UJ	0.1	UJ	0.1	UJ	0.1	UJ	0.1	UJ	0.1	UJ
1,2,3,6,7,8-HxCDD	0.1	0.082	UJ	0.082	UJ	0.082	UJ	0.082	UJ	0.082	UJ	0.082	UJ
1,2,3,7,8,9-HxCDD	0.1	0.064	UJ	0.064	UJ	0.064	UJ	0.064	UJ	0.064	UJ	0.064	UJ
1,2,3,4,6,7,8-HpCDD	0.01	0.085	UJ	0.085	UJ	0.085	UJ	0.085	UJ	0.085	UJ	0.085	UJ
OCDD	0.0003	**0.189**	**J**	**0.329**	**J**	**0.245**	**J**	**0.376**	**J**	**0.671**	**J**	**0.592**	
Furans													
2,3,7,8-TCDF	0.1	**0.678**		**0.503**		**1.06**		**0.364**		**0.866**		**0.708**	
1,2,3,7,8-PeCDF	0.03	**0.086**	**J**	**0.106**	**J**	**0.21**	**J**	**0.096**	**J**	**0.245**	**J**	**0.094**	**J**
2,3,4,7,8-PeCDF	0.03	0.039	UJ	**0.047**	**J**	0.039	UJ	0.039	UJ	0.039	UJ	**0.04**	**J**
1,2,3,4,7,8-HxCDF	0.1	**0.131**	**J**	**0.084**	**J**	0.075	UJ	0.075	UJ	0.075	UJ	**0.116**	**J**
1,2,3,6,7,8-HxCDF	0.1	0.075	UJ	0.075	UJ	0.075	UJ	0.075	UJ	0.075	UJ	0.075	UJ
2,3,4,6,7,8-HxCDF	0.1	**0.085**	**J**	**0.079**	**J**	**0.18**	**J**	0.05	UJ	**0.254**	**J**	0.05	UJ
1,2,3,7,8,9-HxCDF	0.1	0.056	UJ	0.056	UJ	0.056	UJ	0.056	UJ	0.056	UJ	0.056	UJ
1,2,3,4,6,7,8-HpCDF	0.01	0.094	UJ	0.052	UJ	0.052	UJ	0.055	UJ	0.065	UJ	0.052	UJ
1,2,3,4,7,8,9-HpCDF	0.01	**0.128**	**J**	0.085	UJ	0.085	UJ	0.085	UJ	0.085	UJ	0.085	UJ
OCDF	0.0003	**0.284**	**J**	**0.329**	**J**	**0.157**	**J**	**0.179**	**J**	**0.232**	**J**	0.2	UJ
NTR = 0.065 ng/Kg													
TEQ[2]		0.093	J	0.071	J	0.130	J	0.039		0.120	J	0.087	J

[1] = Toxic Equivalent Factor - WHO, 2005.
[2] = Toxic Equivalent Quotient - total toxicity equivalent to 2,3,7,8 TCDD.
UJ = Not detected at the estimated reporting limit shown.
J = Reported result is an estimate.
Bold = Analyte was detected.

Table B5. PCB Results from West Medical Lake Surface Sediment Samples, April 2008 (ug/Kg, dw - parts per billion).

Site ID:	WML01	WML02	WML03	WML04[1]	WML05	WML06	WML07
Date:	4/3/08	4/2/08	4/2/08	4/3/08	4/3/08	4/3/08	4/3/08
Sample ID (08):	144050	144051	144052	144053/7	144054	144055	144056
TOC 70°C (%):	7.3	6.8	6.8	6.3	6.1	7.2	8.0
Fines (%):	66.4 J	75.8	84.4	94.6	95.1	97.2	80.4
PCB - 1016	13 UJ	12 UJ	13 UJ	6.8 U	6.7 U	8.1 U	9.4 U
PCB - 1221	51 UJ	194 UJ	128 UJ	192 UJ	135 UJ	258 UJ	187 UJ
PCB - 1232	51 UJ	73 UJ	51 UJ	6.8 U	54 UJ	8.1 U	9.4 U
PCB - 1242	13 UJ	24 UJ	6.4 U	6.8 U	27 UJ	8.1 U	9.4 U
PCB - 1248	13 UJ	6.1 UJ	6.4 U	6.8 U	13 UJ	8.1 U	9.4 U
PCB - 1254	**11 J**	**17 J**	**16**	**11**	**9.0**	**14**	**19**
PCB - 1260	6.3 UJ	6.1 UJ	6.4 U	6.8 U	6.7 U	8.1 U	9.4 U
PCB - 1262	6.3 UJ	6.1 UJ	6.4 U	6.8 U	6.7 U	8.1 U	9.4 U
PCB - 1268	6.3 UJ	6.1 UJ	6.4 U	6.8 U	6.7 U	8.1 U	9.4 U

1 = The value reported is the mean of a replicate pair.
J = Analyte is positively identified; the result is an estimate.
UJ = Analyte was not detected at the estimated detection limit shown.
U = Analyte was not detected at the detection limit shown.

Table B6. Dioxin and Furan Results from West Medical Lake Sediments, April 2008 (ng/Kg, dw - pptr).

Site ID:	TEF[1]	WML01	WML02	WML03	WML04	WML05	WML06	WML07
Sample ID (08):		144050	144051	144052	144053	144054	144055	144056
Sample Dates:		4/3/08	4/2/08	4/2/08	4/3/08	4/3/08	4/3/08	4/3/08
Parameter								
Dioxins								
2,3,7,8-TCDD	1	**0.60**	**0.56**	**0.76**	**0.37**	**0.29**	**0.35**	**0.32**
1,2,3,7,8-PeCDD	1	**0.71 J**	**0.84**	**0.91**	**0.90**	**0.55 J**	**0.86**	**0.66 J**
1,2,3,4,7,8-HxCDD	0.1	**0.74 J**	**0.48 J**	**0.84**	**0.79**	**0.44 J**	**0.68 J**	**0.45 J**
1,2,3,6,7,8-HxCDD	0.1	**2.5**	**2.0**	**2.6**	**1.9**	**1.6**	**2.1**	**1.9**
1,2,3,7,8,9-HxCDD	0.1	**3.2**	**2.0**	**3.1**	**2.5**	**2.3**	**3.4**	**1.8**
1,2,3,4,6,7,8-HpCDD	0.01	**83**	**74**	**88**	**62**	**45**	**58**	**53**
OCDD	0.0003	**710**	**649**	**745**	**501**	**336**	**420**	**375**
Furans								
2,3,7,8-TCDF	0.1	**10.5**	**8.30**	**9.79**	**7.78**	**5.75**	**10.5**	**10.4**
1,2,3,7,8-PeCDF	0.03	**1.17**	**1.03**	**1.29**	**0.94**	**0.75**	**1.34**	**1.11**
2,3,4,7,8-PeCDF	0.3	**1.48**	**1.05**	**1.42**	**1.21**	**1.00**	**1.35**	**1.24**
1,2,3,4,7,8-HxCDF	0.1	1.47 UJ	1.02 UJ	1.09 UJ	1.01 UJ	0.74 UJ	0.99 UJ	1.05 UJ
1,2,3,6,7,8-HxCDF	0.1	**0.82**	**0.78**	**0.97**	**0.63 J**	**0.5 J**	**0.80 J**	**0.71 J**
2,3,4,6,7,8-HxCDF	0.1	**0.76 J**	**0.91**	**1.06**	**0.79**	**0.41 J**	**0.93**	**0.87**
1,2,3,7,8,9-HxCDF	0.1	**0.13 J**	**0.12 J**	**0.088 J**	**0.098 J**	0.074 UJ	**0.14 J**	**0.075 J**
1,2,3,4,6,7,8-HpCDF	0.01	**13.3**	**13.2**	**15.2**	**10.8**	**7.54**	**7.52**	**7.70**
1,2,3,4,7,8,9-HpCDF	0.01	**0.61 J**	**0.61**	**0.66**	**0.3 J**	**0.40 J**	**0.53 J**	**0.48 J**
OCDF	0.0003	**38.6**	**30.2**	**33.1**	**25.2**	**17.7**	**19.1**	**15.2**
TEQ[2]		4.8	4.3	5.2	4.0	2.9	4.3	3.7
% 2,3,7,8-TCDD		13%	13%	15%	9%	10%	8%	9%
% Dioxins		60%	63%	64%	62%	61%	58%	54%
% Furans		40%	37%	36%	38%	39%	42%	46%

[1] = Toxic Equivalent Factor; WHO, 2005.
[2] = Toxic Equivalent Quotient - total toxicity equivalent to 2,3,7,8-TCDD.
J = The result is an estimate.
UJ = Analyte was not detected at or above the estimated reporting limit shown.
Bold = Analyte was detected.

Table B7. TOC and TSS Results from West Medical Lake Effluent, February, April, July, and October 2008.

Sample ID (08)	Sample ID	Sample Location	Sample Collection[1]		TOC (mg/L)	TSS (mg/L)
			Date	Time		
074000	WMLEFF	Medical Lake WWTP	2/12/08 2/13/08	0820-1500 0820-1510	**3.6**	1 U
184025	WMLEFF	Medical Lake WWTP	4/28/08 4/29/08	0850-1515 0810-1515	**4.3**	1 U
314050	WMLEFF	At old Eastern State Hospital WWTP	7/30/08 7/31/08	0800-1605 0805-1600	**4.5**	1 U
444050	WMLEFF	At old Eastern State Hospital WWTP	10/27/08 10/28/08	0805-1605 0800-1555	NAF	1 U

1 = Effluent samples are composites of AM and PM aliquots collected over two consecutive days.
U = Not detected at the reporting limit shown.
NAF = Not analyzed for. Laboratory instrument malfunctioned - no result.

Table B8. PCB Congener Concentrations in Medical Lake WWTP Effluent, February, April, July, and October 2008 (pg/L, parts per quadrillion).

	Sample Dates:	2/12-13/08	4/28-29/08	7/30-31/08	10/27-28/08
	Sample ID (08):	074000	184025	314050/1[1]	444050/1[1]
PCB Homolog Groups	Mono-	44.5 UJ	71 UJ	41.3 UJ	36.9 UJ
	Di-	**68.5**	**39.7**	**27.4 J**	10 U
	Tri-	**46.6 J**	**35.8 J**	**75.8**	**22.1**
	Tetra-	**16.1**	**19.8**	**9.7 J**	12.7 UJ
	Penta-	10 U	31.6 UJ	**28.2 J**	**11.5 J**
	Hexa-	10 U	15.2 UJ	**11.8 J**	**13.0 J**
	Hepta-	10 U	10 U	10 U	10 U
	Octa-	10 U	10 U	10 U	10 U
	Nona-	10 U	10 U	10 U	10 U
	Deca-	10 U	10 U	10 U	10 U
	Total PCBs	**131 J**	**95.3 J**	**153 J**	**46.6 J**

1 = Results are a mean of a replicate pair. Where one sample analyte was detected and the companion result was not detected, one-half of detection was used in the mean.
Bold = Analyte was detected.
UJ = Not detected at the estimated detection limit shown.
J = The result is an estimate.
U = Not detected at the detection limit shown.

Table B9. Dioxin and Furan Results for the Medical Lake WWTP Effluent, February, April, July, and October 2008 (pg/L, parts per quadrillion).

Sample Date:	TEF[2]	2/13/08		4/29/08		7/31/08		10/28/08	
Sample ID (08):		74000		184025		314050/1[1]		444050/1[1]	
Parameter									
Dioxins									
2,3,7,8-TCDD	1	0.5	UJ	**0.56**	**J**	0.5	UJ	0.5	UJ
1,2,3,7,8-PeCDD	1	1	UJ	1	UJ	1	UJ	1	UJ
1,2,3,4,7,8-HxCDD	0.1	1	UJ	1	UJ	1	UJ	1	UJ
1,2,3,6,7,8-HxCDD	0.1	1	UJ	1	UJ	1	UJ	1	UJ
1,2,3,7,8,9-HxCDD	0.1	1	UJ	1	UJ	1	UJ	1	UJ
1,2,3,4,6,7,8-HpCDD	0.01	1	UJ	1	UJ	1	UJ	1	UJ
OCDD	0.0003	2	UJ	**3.03**	**J**	2	UJ	2	UJ
Furans									
2,3,7,8-TCDF	0.1	0.5	UJ	0.5	UJ	1.17	UJ	1.39	UJ
1,2,3,7,8-PeCDF	0.03	1	UJ	1	UJ	1	UJ	1	UJ
2,3,4,7,8-PeCDF	0.3	1	UJ	1	UJ	1	UJ	1	UJ
1,2,3,4,7,8-HxCDF	0.1	1	UJ	1	UJ	1	UJ	1	UJ
1,2,3,6,7,8-HxCDF	0.1	1	UJ	1	UJ	1	UJ	1	UJ
2,3,4,6,7,8-HxCDF	0.1	1	UJ	1	UJ	1	UJ	1	UJ
1,2,3,7,8,9-HxCDF	0.1	1	UJ	1	UJ	1	UJ	1	UJ
1,2,3,4,6,7,8-HpCDF	0.01	1	UJ	1	UJ	1	UJ	1	UJ
1,2,3,4,7,8,9-HpCDF	0.01	1	UJ	1	UJ	1	UJ	1	UJ
OCDF	0.0003	2	UJ	2	UJ	2	UJ	2	UJ
TEQ[3]		2	UJ	**0.56**	**J**	2	UJ	2	UJ

[1] = Results are for a replicate pair. Where detection limits are different, the higher is shown.
[2] = Toxic Equivalent Factor; WHO, 2005 (Van de Berg et al.).
[3] = Toxic Equivalent Quotient - total toxicity equivalent to 2,3,7,8-TCDD.
UJ = Analyte was not detected at or above the estimated reporting limit shown.
J = The result is an estimate.