DEPARTMENT OF
ECOLOGY
State of Washington

PBDE and Dioxin/Furans in Spokane Stormwater

A Supplemental Report

February 2009
Publication No. 09-03-010

Publication and Contact Information

This report is available on the Department of Ecology's website at
www.ecy.wa.gov/biblio/0903010.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, BRWA0004.

Ecology's Study Tracker Code for this study is 07-152-01.

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PBDE and Dioxin/Furans in Spokane Stormwater

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Abstract

Historically, concentrations of polybrominated diphenylether flame retardants (PBDEs) and dioxins in fish from the Spokane River have been elevated. These high levels spurred sampling during 2007 of water and sediment from 14 City of Spokane storm drains discharging directly to the river.

Stormwater samples from manholes were collected during 3 storm events and measured for PBDEs. In addition, 7 sediment samples were collected during a dry period and measured for dioxin/furans, total organic carbon (TOC), and grain size. These samples were collected opportunistically, alongside other samples taken for the *Spokane River PCB TMDL Stormwater Loading Analysis* by Parsons and Terragraphics.

PBDEs were detected in 7 of 14 stormwater samples, with concentrations ranging from 0.002 to 0.023 ug/L. Dioxin/furans were detected in 7 of 14 sediment samples with concentrations ranging from 0.065 to 17.7 ng/Kg TEQ.

The data collected will be used to help prioritize storm-drain systems for further source - tracking efforts.

Acknowledgements

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

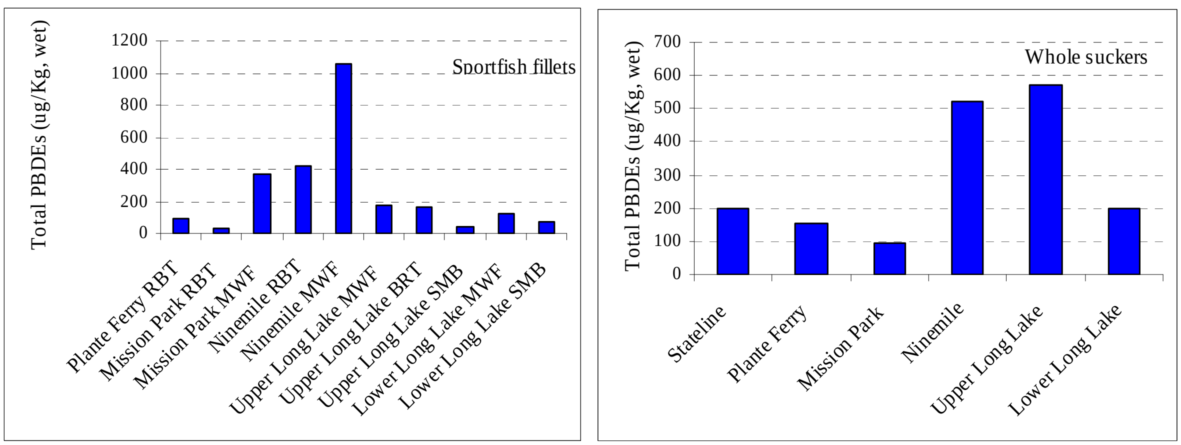
- Richard Jack, King County.
- City of Spokane.
- Terragraphics, Inc.
- Washington State Department of Ecology staff:
    - John Roland, Toxics Cleanup Program, for project idea and support.
    - Manchester Environmental Laboratory staff for data quality review.
    - Randy Coots, Dale Norton, Arianne Fernandez, and David Moore for report review.
    - Joan LeTourneau and Cindy Cook for formatting and editing the report.

Introduction

PBDEs in Fish

Historical fish tissue studies in Washington have found elevated PBDE levels in fish from the Spokane River, ranging from 20-1250 ug/Kg wet weight (ww) (Johnson and Olsen, 2001; Johnson et al., 2006; Seiders et al., 2007). The 3-species average was 740 ug/Kg ww, an order of magnitude above the other 20 waterbodies surveyed (Johnson et al., 2006).

Results from an intensive 2005 fish survey of the Spokane River indicated PBDEs are already elevated at the Idaho border and increase moving downstream, reaching a peak at Nine Mile Reservoir (the eastern city limit of Spokane). One 2005 sample contained PBDEs at 1059 ug/Kg ww. Downstream of Nine Mile, PBDE concentrations decrease. Results are shown in Figure 1 (Serdar and Johnson, 2006).



RBT = rainbow trout; MWF = mountain whitefish; SMB = smallmouth bass.

Figure 1. 2005 data on PBDEs in Spokane area fish (Serdar and Johnson, 2006).

Recommendations from the fish survey were to conduct further investigations into the sources of PBDEs to the river (Serdar and Johnson, 2006).

PBDEs have been produced and used extensively for the last 30 years as flame retardants in computers, TVs, furniture, carpet pads, cars, and other applications. There are 3 main types of PBDEs used in consumer products: Penta-BDE, Octa-BDE, and Deca-BDE. Each of these types of PBDEs has different uses and different toxicity. PBDEs have been found in human breast milk, blood and fat, house dust and indoor air, fish, wildlife, food, and sediments. There are no water quality or fish tissue standards for PBDEs.

Dioxins in Fish

The Washington State Toxics Monitoring Program (WSTMP) collects fish statewide on an annual basis to assess toxic chemicals. Fish tissue from the WSTMP in the Spokane area was found to have elevated levels of dioxin.

Table 1 shows the 4 listings for edible fish tissue that exceed Washington State's human health-based water quality criteria, known as the National Toxics Rule (NTR). The NTR criteria are based on a daily fish consumption rate of 6.5 grams/day and a human health cancer risk level of 10^{-6} for long-term exposure.

Table 1. Washington State Water Quality Assessment for dioxins (2,3,7,8-TCDD) in edible fish tissue.

Listing ID	Category	WRIA	Waterbody Name
42411[1]	5	54	Spokane River
42410[1]	5	54	Spokane Lake
51586[2]	5	54	Spokane River
51587[2]	5	57	Spokane River

[1] – 2004 303(d) Listings.
[2] – Proposed 2008 303(d) Listings.
WRIA – Water Resource Inventory Area.

The term dioxin is often used to represent the group of chemicals designated as polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). The U.S. Environmental Protection Agency (EPA) considers 2,3,7,8-TCDD (tetrachlorodibenzo-*p*-dioxin) to be one of the most potent reproductive/developmental toxicant known. Ecology's policy since 2006 is to place Category-5-impaired waters on the 303(d) list based on the 2,3,7,8-TCDD concentrations.

Dioxins are unintended by-products found in association with certain industrial sites, waste incinerators, and combustion in the presence of chlorine. Dioxins have no commercial or domestic applications and are not intentionally produced, except for small quantities used in research. Pulp and paper mills were a major historical source of dioxins in the Pacific Northwest. Use of chlorine in their bleaching process was discontinued in the 1990s. Nationwide, reductions in dioxin emissions have occurred from a combination of regulatory activities, improved emission controls, voluntary actions on the part of industry, and the closing of a number of facilities (Yake et al., 1998).

Dioxins enter waterbodies through a combination of direct discharge, runoff, and atmospheric deposition. Deposition occurs because these compounds are sufficiently volatile to evaporate and then deposit in cooler regions. In the absence of local sources, PCB and dioxin levels can be elevated solely due to atmospheric deposition from outside sources. Contamination of polar and mountain lake food webs with PCBs, dioxins, and other organo-chlorines has been attributed to atmospheric sources (Johnson, 2008).

A common method used to report total dioxin/furans is the calculated toxicity equivalents (TEQs). TEQs are the sum of the detected dioxin and furan congeners in a sample multiplied by their toxicity equivalency factor (TEF) from the World Health Organization (WHO, 2005). A more detailed discussion is provided in Appendix A.

Study Design

Stormwater may represent a mechanism to transport PBDEs and dioxins to the Spokane River. In 2006, Ecology commissioned a stormwater technical study for PCBs to supplement data for the PCB Total Maximum Daily Load (TMDL) in progress on the Spokane River (Parsons, 2007). Fourteen sites were selected as part of the PCB TMDL, and sampling for PBDEs and dioxins took place as part of the PCB sampling effort in the spring of 2007. The purpose of this study was to evaluate the city of Spokane storm conveyance system as a source of PBDE and dioxin contaminants. In addition, the data will be used to prioritize future source -tracking efforts. This report summarizes the results of PBDEs and dioxin analysis of stormwater from the city of Spokane.

Study Area

Three regions within the Spokane city limits were targeted as part of the larger stormwater study. From upstream to downstream, the first region of interest is from the eastern boundary of the city limit westward to the Mission Street Bridge. The second region is between the Mission Street Bridge and Howard Street Bridge. The third region is downstream of the Howard Street Bridge to the western boundary of the city limit, near the Seven Mile Road Bridge.

Terragraphics Inc. collected stormwater and storm-drain sediments from the same 14 stormwater monitoring sites as the 2006 stormwater technical study. The storm drains sampled during this 2007 study are believed to drain 73% of the city area (Parsons, 2007). The sample site descriptions and location details are listed in Appendix A.

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Methods

Field Sampling

Stormwater samples were collected during 3 storm events: May 2 and 21 and June 5, 2007 and analyzed for PBDEs. Stormwater was collected directly into clean sample jars using a hand-held pole from a manhole access. A detailed methods description with bottles, holding times, and sampling procedures for decontamination can be found in the Quality Assurance Project Plan.

Sediment grab samples were taken from 7 of the 14 locations on April 11, 2007. Manhole sediments were collected using a discrete sampling device. Samples were handled and homogenized using pre-cleaned stainless steel scoops, spoons, and bowls. Homogenized samples were placed in glass sample jars and placed on ice immediately. Notes from the sample collection are listed in Table 2. Where insufficient material was available, planned analyses were prioritized as follows: dioxin/furans, total organic carbon (TOC), and grain size. The minimum size container for each analysis was 8 oz., 2 oz., and 8 oz., respectively.

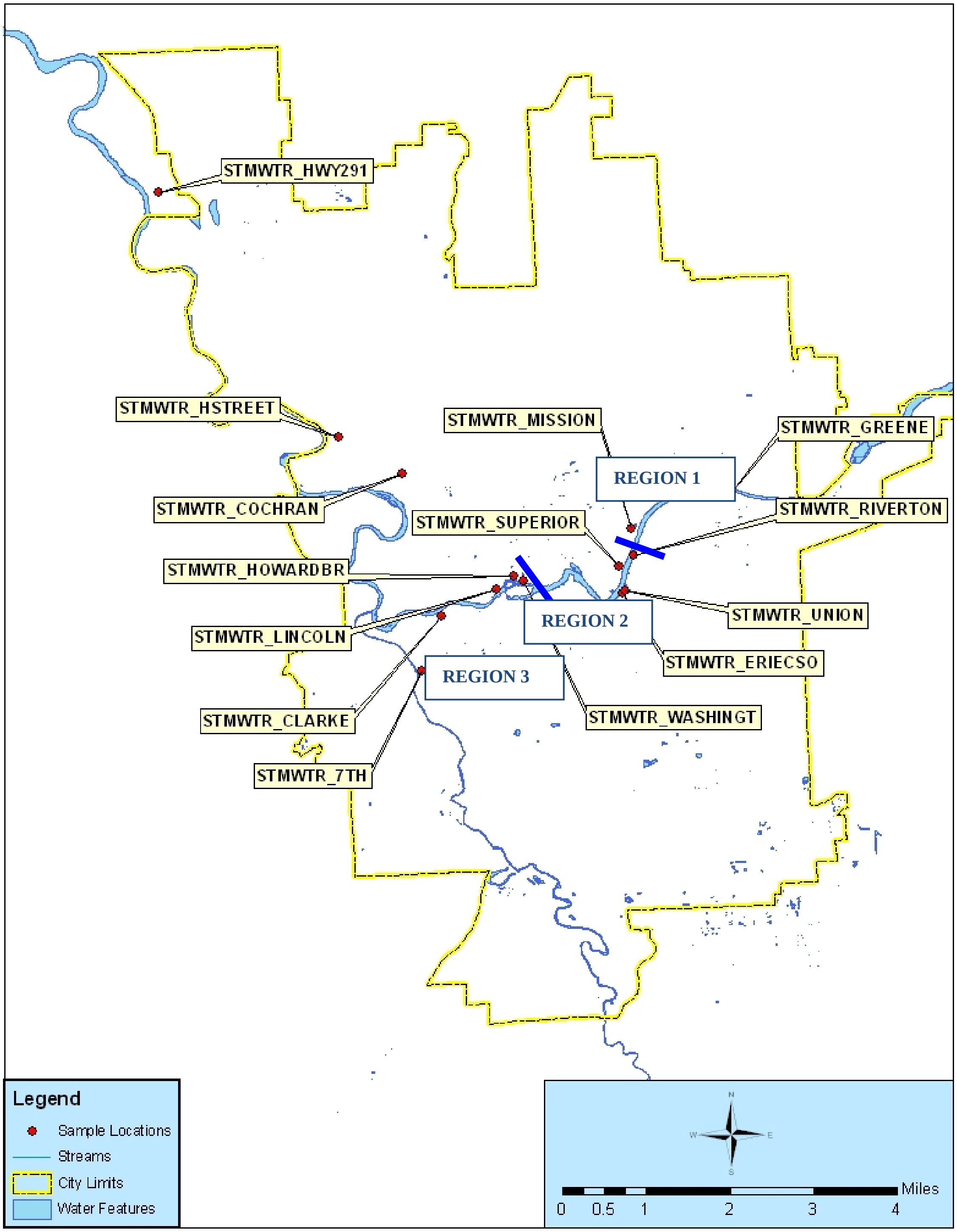

Figure 2. Spokane city limits and storm-drain sampling sites (Parsons, 2007).

Table 2. Spokane sediment sampling summary for April 11, 2007.

Location ID[1]	Lab Number	Full Sample	Partial Sample <250 ml	No Sample	Comments
Region 1					
Greene	4219		x		Collected all sediment at the bottom of the storm drain.
Mission	4224	x			Enough sediment for duplicates.
Riverton	4218			x	No sediment in the bottom of the storm drain. River backed up into pipe.
Region 2					
Superior	4222		x		Collected all sediment at the bottom of the storm drain.
Union	4217		x		Collected all sediment at the bottom of the storm drain.
Erie CSO	4223			x	No sample was collected because this site is a Combined Sewer Overflow (CSO); had standing water.
Washington	4221		x		Collected all sediment at bottom of the storm drain; only enough for 250-mL and a 2-oz jar.
Howard Bridge	4216		x		Collected all sediment at the bottom of the storm drain. Sample container broke in transit.
Region 3					
Lincoln	4214			x	No sediment in the bottom of the storm drain.
Clarke	4215			x	No sediment in the bottom of the storm drain.
7th Avenue	4211			x	No sediment in the bottom of the storm drain.
Cochran	4213			x	No sediment in the bottom of the storm drain.
H Street	4212		x		Collected all sediment in the bottom of the storm drain.
Hwy 291	4210	x			Samples were sandy.

1 = In EIM, these location IDs have the prefix "STMWTR_".

Laboratory Analysis

The Ecology/EPA Manchester Environmental Laboratory (MEL) analyzed the stormwater samples for PBDEs and the sediment samples for TOC. MEL contracted out the analyses for dioxins to Pacific Rim Laboratories, Inc., British Columbia, and grain size analysis to Analytical Resources, Inc. (ARI), Seattle, WA. Target compounds, reporting limits, and analytical methods are listed in Table 3.

Table 3. Target compounds, reporting limits, and analytical methods.

Matrix and Analyte	Reporting Limit	Analytical Method
Stormwater		
PBDEs	0.05 ug/L	EPA 8270
Sediment		
Dioxins/furans	0.3 ng/Kg, dw	EPA 1613B
Total organic carbon	0.1%	PSEP (1986)
Grain Size	0.1%	PSEP (1996)

PSEP = Puget Sound Estuarine Protocols.

Data Quality

The quality control (QC) procedures routinely used by MEL and their contractors were followed for this project. Measurement quality objectives for this project were met, with the exception that fewer than desired storm-drain sediment samples were collected for dioxin, TOC, and grain size analysis.

MEL and the contracted laboratories prepared written case narratives assessing the quality of the project data. These reviews include description of the analytical methods and an assessment of holding times, initial and continuing calibrations and degradation checks, method blanks, surrogate recoveries, laboratory control samples, and laboratory duplicates. The reviews and the complete MEL data reports are available on request.

Three sets of replicates were taken for PBDE samples. However, due to non-detections, there is only one pair of samples where the replicate concentrations could be assessed. Two field replicates from Howard Bridge was collected to obtain an estimate of field and laboratory precision. Precision is often reported as the relative percent difference (RPD) for pairs of data and the relative standard deviation (RSD) of the results of multiple measurements. RPD is the percentage of the difference between the pair divided by the mean, and RSD is the percentage of the standard deviations divided by the mean.

Only one field location, Howard Bridge, set of stormwater replicates had PBDE detections. The Howard Bridge triplicate RSDs ranged from 25 to 13% for PBDE-47 and PBDE-99, respectively. The total PBDE sum of congeners RSD for Howard Bridge was 13.8%, which is considered acceptable for stormwater PBDE concentrations.

Some of the dioxin data are qualified as "J" because they were below the lowest calibration range. "J" flags are detections where the numerical value is considered an estimate. PBDE results with qualifiers "J" or "NJ" were qualified based on low surrogate recoveries. The "NJ" flag denotes there is tentative evidence that the analyte is present. The associated numerical result is an estimate.

Two sites had enough sediment collected for a pair of dioxin/furans field replicates, Mission and Hwy 291. The RPDs for these ranged from 52% for the Mission replicates to 107% for the Hwy 291 replicates. The poor precision for the storm-drain sediments may be due to at least three factors:

1. Sediment precision is characteristically poor.
2. Resultant small numbers.
3. Non-homogenous nature of these contaminants.

Hwy 291 results were very small numbers. Storm-drain sediments were manually homogenized in steel bowls. However, the contaminants may not be uniformly distributed in the sediment matrix. Table 4 shows the replicate precision for the replicated samples.

Table 4. Field replicate precision results for dioxins and PBDEs from storm-drain sediments.

Location	Sample	Rep 1	Rep 2	Average	Standard Deviation	%RPD	%RSD
PBDEs (ug/L)							
Howardbr (Total PBDEs)	0.017	0.015	0.013	0.015	0.002	na	13.8
HowardBr (PBDE-047)	0.012	0.008	0.008	0.009	0.002	na	25.1
HowardBr (PBDE-099)	0.005	0.007	0.005	0.006	0.001	na	12.9
Dioxin/Furan Calculated TEQ (ng/Kg)							
Hwy 291	0.11 J	0.07 J	na	0.09	0.03	51%	na
Mission	4.20	13.92	na	9.06	6.88	107%	na
Total Organic Carbon (%)							
Mission TOC	3.42	3.27	na	3.35	0.11	4%	na
HWY 291 TOC	0.22	0.18	0.21	0.20	0.02	na	10%
Grain Size (%)							
Mission field replicate fines (silt + clay)	13.6	25.3	na	19.45	8.27	60%	na
Mission lab replicate fines (silt + clay)	20.9	24.8	na	22.85	2.76	17%	na
Mission overall fines (field + lab replicates)	na	na	na	21.15	5.40	na	26%

Rep = replicate.
J = The analyte was positively identified. The associated numerical result is an estimate.
na = not applicable.

The poor precision for the sediments at Hwy 291 may also be related to the higher level of gravels with fewer fines. The RSD for TOC field replicates from the Hwy 291 storm drain was 10%. TOC RPDs for the field replicates from the Mission storm drain was 4%. The laboratory ran a pair of duplicates on one sample from the Mission storm drain. The results were within an expected range for precision. The RSD for the combined field replicates and laboratory duplicates was 26%.

Results and Discussion

PBDEs in Water Samples

Table 5 summarizes the data obtained on PBDE levels in the city of Spokane stormwater. The complete data sets for individual PBDEs are available in Appendix C.

Table 5. Total PBDE concentrations for storm drains by region (ug/L).

Sampling Date:	May 2, 2007		May 21, 2007		June 5, 2007	
Region 1: Eastern city limits to Mission Street						
STMWTR_GREENE	0.053	U			0.048	U
STMWTR_MISSION	**0.002**	**NJ**			**0.004**	**J**
Region 2: Mission Street to Howard Bridge						
STMWTR_RIVERTON	**0.004**	**NJ**	0.060	U	0.060	U
STMWTR_SUPERIOR	0.05*	U			**0.003**	**NJ**
STMWTR_UNION	0.050	U	0.051	U	**0.0068**	
STMWTR_ERIECSO	**0.023**				**0.005**	
STMWTR_WASHINGT	**0.003**	**J**	0.05*	U	**0.0046**	
STMWTR_HOWARDBR	0.050	U	0.050	U	**0.015***	
Region 3: Howard Bridge to western city limits						
STMWTR_LINCOLN	0.050	U	0.051	U	0.048	U
STMWTR_CLARKE	0.090	U	0.050	U	**0.005**	**NJ**
STMWTR_7TH	**0.004**	**NJ**	0.050	U	**0.007**	**NJ**
STMWTR_COCHRAN	0.060	U	0.050	U	**0.010**	
STMWTR_HSTREET	0.050	U	0.050	U	0.050	U
STMWTR_HWY291	0.050	U	0.051	U	0.048	U

*average of three field replicates.
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.
NJ = There is evidence that the analyte is present. The associated numerical result is an estimate.
Bold results are to aid the reader by distinguishing detections.

PBDE concentrations ranged from 0.002 to 0.023 ug/L. There were two detections at the eastern edge of the city limits in Region 1. The frequency and concentrations of PBDE detections in the stormwater increased through Region 2, and then decreased in frequency and concentrations in the western storm drains, Region 3. The results were highest in the Erie CSO storm-drain water.

The Spokane River water column PBDE concentrations were 0.00093 and 0.00015 ug/L for the 2005 fall and spring deployments, respectively, much lower than in stormwater (Johnson et al., 2006).

Relatively few stormwater studies on PBDEs are available for comparison. The following two studies of municipal wastewater effluent concentrations are included for general comparison purposes.

1. A single sampling in June 2007 of wastewater discharge from 7 treatment plants on the Yakima River found PBDE concentrations at the Yakima and Prosser plants were 0.018 and 0.026 ug/L, respectively. The remainder 5 plants average was 0.005 ug/L. (Norton, 2009).

2. Wastewater effluent in Palo Alto, California sampled for PBDEs from a 3-day composite sample found the mean total PBDE was 0.029 ug/L. This effluent discharges to San Francisco Bay and was considered a significant point (discrete) source of PBDEs to the bay (North, 2004).

This comparison clarifies that the stormwater concentrations observed in Spokane are similar to the municipal effluent concentrations of PBDEs in both Washington and California.

For a larger perspective, stormwater runoff from the September 11, 2001 attacks on the World Trade Center in New York were monitored for high concentrations of PCBs, PBDEs, dioxins, and furans. Total PBDE concentrations in runoff measurements at Rector Street reached 585 ug/L three days after the attack and dropped to 0.22 ug/L by September 20, 2001 (Litten et al., 2003).

Dioxin and Furans in Sediment Samples

Sediments were collected from the 7 of the storm drains on April 11, 2007, prior to the spring storms. Fewer than anticipated samples were collected due to the lack of sediment in the storm drains. Results are presented in Table 6.

The dioxin TEQ is calculated by multiplying the result for each congener by its congener-specific toxicity equivalency factor (TEF), developed by the World Health Organization in 2005. Summing the products obtains the 2,3,7,8-TCDD TEQ. All individual congener results are provided in Appendix C.

Sampling results are presented as the 2,3,7,8-TCDD dioxin concentration and the calculated dioxin TEQ in Table 6 (Vanden Berg et al., 2005). Not every storm-drain sediment sample contained detected concentrations of 2,3,7,8-TCDD. The dioxin calculated TEQs are based on the sum of all detected congeners.

Guidelines

Washington State does not have a numerical regulatory standard for dioxin in freshwater sediments. However, proposed sediment standards containing numerical criteria are the Apparent Effects Threshold (AET) of 8.8 ng TCDD TEQ/Kg dw (Cubbage et al., 1997). The AET approach is used to predict adverse biological effects in freshwater sediments.

In March 2005, Canadian environmental guidelines were developed for dioxins and furans in sediments. The interim sediment quality guideline is 0.85 ng TCDD TEQ /Kg dw. This guideline is based on the 17 co-planar congeners which are thought to be the most toxic. A probable effect level (PEL) was also determined as an additional assessment tool. The PEL for freshwater sediments is 21.5 ng TCDD TEQ /Kg dw (Environment Canada, 2005).

Multiple sediment criteria are shown in Table 6.

Table 6. Washington State guidance criteria for TCDD.

Numerical Criteria	TEQ ng/Kg, dw	Reference
Proposed Apparent Effects Threshold (AET)	8.8	Cubbage et al., 1997
Method B soil cleanup standard	6.67	Chapter 173-340 WAC
Wildlife protection soil screening value	2	Chapter 173-340 WAC
Canadian interim sediment guideline	0.85	Environment Canada, 2005
Canadian probable effects level	21.5	Environment Canada, 2005

The two Canadian thresholds for dioxin are separated by two orders of magnitude. The proposed Washington AET is directly in-between these two values.

The Spokane storm-drain sediment results are shown in Table 7.

The overall study mean and median TEQs are 9.77 and 10.01 ng/Kg dw, respectively. Five of the 9 dioxin/furan TEQ results are above the Washington State proposed AET but below the Canadian PEL. The highest concentrations were found in Region 2 storm drains, with a mean of 16.3 ng/Kg dw.

The reason for the large difference between the Mission storm-drain sediment replicates is unknown but may be due to poor sample mixing or the non-homogenous nature of the contaminants in the sediment matrix. The H Street drain reporting limit for non-detect of TCDD was 1.5 ng/Kg, much higher than other field sites, which may indicate a matrix interference in this sample.

Table 7. Dioxin and furan concentrations from storm-drain sediments.

Storm Drain Location	Lab ID	2,3,7,8-TCDD ng/Kg dw	Dioxin/Furan Total TEQ ng/Kg dw
Region 1			
Greene	7154219	0.38 J	10.01
Mission	7154224	<0.3	4.20
Mission (field replicate)	7154225	0.52 J	13.92
Region 2			
Superior	7154222	0.57 J	17.71
Union	7154217	0.63 J	17.30
Washington	7154221	0.51 J	13.85
Region 3			
H Street	7154212	< 1.5	5.86
Hwy 291	7154210	<0.3	0.11 J
Hwy 291 (field replicate)	7154210-Rep1	<0.3	0.065 J

J = The analyte was positively identified. The associated numerical result is an estimate.

For comparative purposes, the following are data reported for soil or sediments from other areas in Washington State as well as one natural background example from a national study by EPA.

1. The Superfund cleanup site around American Crossarm had freshwater sediment TEQ concentrations from Dillenbaugh Creek ranging from 3.7-790 ng/Kg with a mean of 308 ng/Kg (Blakley and Norton, 2005).

2. In 2008, dioxin and furan TEQs from Greater Elliot Bay sediments ranged from 0.67-25.6 ng/Kg in 5 discrete samples. The mean and median levels were 9.70 and 7.67 ng TEQ/Kg dw, respectively (Sloan and Gries, 2008).

3. In another Ecology study (Yake et al., 1998), the concentrations of dioxins in soils across Washington State were characterized by land use (Table 8). The study assessed the typical (or background) concentrations of dioxins in TEQ equivalents. Of 84 soil samples, dioxins were detected in every sample; the significance of these relationships was not assessed.

   Table 8. Summary of dioxin concentrations in Washington State soils by land use (reported as TEQ, ng/Kg).

Land Use	Range	Mean	Median	Number of Samples
Urban	0.13 – 19	4.1	1.7	14
Forest	0.03 – 5.2	2.3	2.2	8
Open	0.04 – 4.6	1.0	0.27	8
Agricultural	0.008 – 1.2	0.14	0.05	54

4. Dioxin and furan TEQs from the *Draft* Remedial Investigation on the lower Duwamish River found the mean and median concentrations for the 47 sediment samples to be 92.7 and 10.2 ng TEQ/Kg, respectively. The natural urban background dioxin and furan TEQ value was 0.52 ng/Kg dw, from 12 bays in western Washington (WindWard Environmental, 2007).

5. The range of dioxin and furan TEQs in sediments of 11 lakes and reservoirs throughout the U.S., which were selected to represent background conditions in areas removed from known sources, was 0.12 to 16.3 ng/Kg dw, with an arithmetic mean of 5.3 ng/Kg dw (EPA, 2000).

Comparing mean values for each study places the results of this 2007 study above average levels for national lakes (EPA, 2000) and natural urban background levels for western Washington bays. However, the results of this study are well below the average for the contaminated lower Duwamish Waterway in King County and American Crossarm site at Dillenbaugh Creek in Lewis County.

The land uses associated with the Spokane stormwater sediments encompass the range of open and urban land uses in the Yake study. This seems reasonable considering the topography and land use of the area in and around the city of Spokane.

Sediment Grain Size and Total Organic Carbon

Results for grain size and TOC are listed in Table 9. Only 2 of 14 had enough sediment for a grain size analysis and 5 of 14 samples had sediment for TOC analyses. All sediment grain size and TOC data are available in Appendix C.

Table 9. Grain size analysis and TOC results for storm-drain sediments (%).

Storm Drain	Laboratory ID	Gravel	Sand	Silt	Clay	Fines (silt/clay)	TOC
Hwy 291	7154210	24.2	75.4	0	0	0.3	0.2
Mission	07154224*	31.8	45.8	16.5	2.9	19.5	3.4
Union	7154217	na	na	na	na	na	2.1
Washington	7154221	na	na	na	na	na	6.9
H Street	7154212	na	na	na	na	na	55.1

* Mean of field replicates.
na = not applicable.

Sediments collected at Mission and Hwy 291 storm drains were primarily gravel and sand. Fines are the sum of silt plus clay fractions and were very low at Hwy 291 and low at Mission.

TOC measures the organic content of the sediment. Of the 5 storm-drain sites analyzed, only H Street had TOC values as high as 55%. This value is atypical and required reassessment by Manchester Laboratory. It is unknown why such a high TOC value was found in sediments. The remaining sites had low values, ranging from 0.2 to 6.9%.

An unusually high organic content in storm-drain sediments may indicate the source is erosion of soils, illicit connections, dumping, or hydrocarbon spills. In surface waters, high TOC measurements may affect oxygen levels of the water column. Also, high TOC can indicate the presence of toxic substances and may help lead to a source of organic material that could be a source of pollution.

The complete data set for this 2007 study is available upon request from the author. These data can also be found in Ecology’s Environmental Information Management (EIM) database under the project ID of BRWA0004.

Conclusions and Recommendations

As a result of this 2007 study, the following conclusions and recommendations are made.

Conclusions

Low concentrations of PBDEs were detected in stormwater from 10 of the 14 storm drains sampled. The highest PBDE concentrations were found in Erie CSO and Howard Bridge storm-drain sediments.

All 7 storm-drain sediments had detectable levels of dioxin/furans. The highest concentrations were from Region 2, corresponding to the stormwater catchments from Superior Street and Union Street The Region 2 concentrations indicate sources of elevated dioxins from somewhere in the city of Spokane, although the levels are well below levels seen at the lower Duwamish River in King County.

Grain size analysis on two storm drains indicates between 60-80% of the sediment was gravel and sand. Fines made up <1 to 25% of the samples.

Total organic carbon (TOC) levels for all but one storm drain were low, with the exception of H Street which was found to contain 55% TOC. The source of the carbon in this stormwater catchment is unknown.

Both PBDE concentrations in stormwater and dioxin/furan concentrations in storm-drain sediment seem to be at the typical range for Washington urban areas based on the little data available for comparisons. Because both PBDEs and dioxin/furans are persistent and toxic compounds, their constant loading to the Spokane River from the stormwater system represents a significant point source.

Recommendations

Results from this study represent the first known tests for PBDEs and dioxin/furans in stormwater or storm-drain sediment. Stormwater is a conduit for carrying pollutants from sources to a destination and is not actually a source itself. Therefore, sources for the contaminants in this study could be traced up the storm-drain system to identify pollutant sources. In particular the source of carbon in the H Street catchment should be examined. Source tracking should also focus on the Erie CSO site for PBDEs and the Superior and Union sites for dioxin/furans.

Other storm drains or sources of PBDEs and dioxins should be investigated. Priority should be given to screening industrial, municipal discharges, and storm drains not examined by this study.

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Appendices

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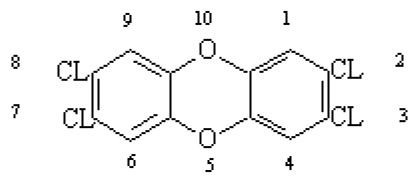
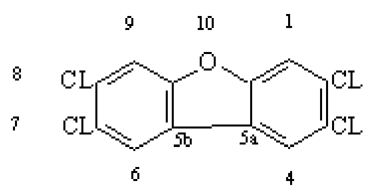
Appendix A. Dioxins and Furans

There are 210 different forms (or congeners) of polychlorinated dibenzo-p-dioxins (dioxins) and polychlorinated dibenzofurans (furans). These are identified by the number and location of chlorine atoms on the molecule. The most toxic of these congeners have chlorine atoms at four specific sites (the 2,3,7, and 8 positions).

Figure A-1 shows the structure and numbering system for these congeners. The most toxic of the dioxins is 2,3,7,8-tetrachloro dibenzo-p-dioxin (2,3,7,8-TCDD). The 16 other dioxins and furans with chlorines at the 2,3,7 and 8 positions have been assigned toxicity values relative to 2,3,7,8-TCDD. The number system for 2,3,7,8-tetrachloro-dibenzofuran (2,3,7,8-TCDF) is shown in the chemical structure below.



TCDD



TCDF

Figure A-1. Chlorinated Dioxin and Furan Structures.

These relative toxicity values are called toxicity equivalency factors (TEFs). 2,3,7,8-TCDD and 1,2,3,7,8-PeCDD in the WHO 2005 TEFs are assigned a TEF of 1, and the other congeners and furans are assigned values less than 1 (Van den Berg et al, 2005). TEFs are used to express a total toxicity of dioxins when the concentration of each congener is multiplied by its TEF and all the products are added up (called dioxin equivalents or TEQs).

Concentrations of dioxins and furans in the environmental media (e.g., wastewater, tissue, ash) are typically expressed as TEQs.

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Appendix B. Storm Drain Sampling Locations

Table B-1. Location Descriptions.

Location ID	Manhole Number	Depth to Bottom (ft)	Location Description
Region 1: Eastern city limits of Spokane to Mission Street			
Greene	1680120ST	9.5	South of the Greene Street Bridge, located on the sidewalk east of the bridge.
Mission	1400224ST	unknown	Northeast of the intersection of Perry Street and Mission Avenue near Avista.
Region 2: Mission Street to Howard Bridge			
Riverton	1800130ST	12	At the intersection of South Riverton Avenue and Desmet Avenue, on the river side of the guardrail. Manhole cover says "Sewer" is painted green.
Superior	1300136ST	9	In the middle of Superior Street, south of Cataldo Avenue. Use cones for traffic safety. Previously sampled site.
Union	1382924ST	7	In the middle of the street in front of the Union Gospel Mission, just south of the intersection of Erie Street and Trent Avenue.
Erie CSO	0521966CD	10.5	South of Trent Avenue on Erie Street. South of MH#1382924ST. Middle of 3 manhole covers in parking area of park. This is a CSO. Previously sampled site.
Washington	1100230ST	7	North and west of Washington Street Bridge. Located where the two paved walking trails converge. Previously sampled site.
Howard Bridge	1000124ST	7.5	Northeast of Howard Bridge (walking bridge), just south of intersection with Mallon Avenue. In the middle of the trail/road. South of circle, approximately 12 feet east of Catch Basin, near map sign.
Region 3: Howard Bridge to western city limits of Spokane			
Lincoln	0906615IN	7.5	Catch basin in sidewalk east of Lincoln Street next to Anthony's Restaurant, north of Post Street Bridge.
Clarke	1900330ST	23.5	Off north side of curb of Clarke Street, east of Elm Street. This is CSO 24A.
7th Street	2000318ST	3.5	Next to light pole on southeast side of curb at Intersection of 7th Street and Inland Empire. Labeled "Sewer".
Cochran	0501142ST	20	In the middle of Cochran Street, north of Grace Avenue. West of TJ Meenach Drive. Southern (and downstream) of 2 manholes. There is an alternate manhole at the bottom of the hill from this manhole (MH# 0501042ST) with a depth to bottom of 14 feet.
H Street	0400621ST	4.5	In the middle of H Street next to the alley north of Glass and south of Northwest Boulevard.
Hwy 291	0106136ST	9	Near the southwest corner of the intersection of Parkway Road and Ninemile Road, off to the side of the road just before heading down the hill to the river. Near Seven Mile Bridge.

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Appendix C. Dioxin and Furan, PBDE, and Grain Size Data

Table C-1. Dioxin and Furan Results for Sediments (ng/Kg dw, ppt).

Site:	STMWTR_ GREENE 07154219[2]	STMWTR_ HSTREET 07154212	STMWTR_HWY291		STMWTR_MISSION (field replicates)		STMWTR_ SUPERIOR 07154222	STMWTR_ UNION 07154217	STMWTR_ WASHINGT 07154221
			7154210	07154210-rep	07154224	07154225			
1,2,3,4,6,7,8-HpCDD	244	201	7.29 J	3.44 J	112	224	365	363	323
1,2,3,4,6,7,8-HpCDF	63.3	52.1	2.11 J	1.96 J	28.5	65.6	98.7	91.7	90.5
1,2,3,4,7,8,9-HpCDF	3.8 J	7.5 UJ	1.5 UJ	1.5 UJ	1.5 UJ	10.4 J	4.07 J	5.3 J	5.1 J
1,2,3,4,7,8-HxCDD	4.29 J	7.5 UJ	1.5 UJ	1.5 UJ	1.5 UJ	2.93 J	7.03 J	3.72 J	3.61 J
1,2,3,4,7,8-HxCDF	3.66 J	7.5 UJ	1.5 UJ	1.5 UJ	2.6 J	29	4.46 J	6.07 J	2.94 J
1,2,3,6,7,8-HxCDD	10.7 J	7.5 UJ	1.5 UJ	1.5 UJ	5.33 J	9.55 J	17.5	14.2 J	14.3 J
1,2,3,6,7,8-HxCDF	3.36 J	7.69 J	1.5 UJ	1.5 UJ	2.96 J	10.1 J	5.25 J	4.79 J	5.34 J
1,2,3,7,8,9-HxCDD	8.03 J	7.5 UJ	1.5 UJ	1.5 UJ	2.86 J	3.74 J	12.4 J	13.6 J	9.27 J
1,2,3,7,8,9-HxCDF	1.5 UJ	7.5 UJ	1.5 UJ	1.5 UJ	1.5 UJ	5.45 J	1.58 J	1.81 J	1.5 UJ
1,2,3,7,8-PeCDD	1.59 J	7.5 UJ	1.5 UJ	1.5 UJ	1.5 UJ	2.3 J	4.57 J	4.24 J	3.12 J
1,2,3,7,8-PeCDF	2.18 J	7.5 UJ	1.5 UJ	1.5 UJ	1.5 UJ	8.56 J	2.15 J	3.36 J	2.03 J
2,3,4,6,7,8-HxCDF	5.02 J	20.6	1.5 UJ	1.5 UJ	5.67 J	5.42 J	9.36 J	11 J	8.44 J
2,3,4,7,8-PeCDF	2.1 J	7.5 UJ	1.5 UJ	1.5 UJ	1.09 J	1.5 UJ	2.14 J	2.35 J	1.66 J
2,3,7,8-TCDD	0.38 J	1.5 UJ	0.3 UJ	0.3 UJ	0.3 UJ	0.52 J	0.57 J	0.63 J	0.51 J
2,3,7,8-TCDF	0.96 J	2.88 J	0.3 UJ	0.3 UJ	2.28 J	7.15	3.97	3.36	3.17
1,2,3,4,6,7,8,9-OCDD	1950	662	53.3	35	911	1570	3130	3360	2330
1,2,3,4,6,7,8,9-OCDF	143	56.2	3 UJ	3 UJ	72.4	141	316	547	241
Calculated TEQ[1]	10.006	5.863	0.110 J	0.065 J	4.197	13.924	17.713	17.303	13.853

(1) = TEQ = Total Equivalent Toxicity is calculated as concentration times Toxicity Equivalency Factor developed by WHO (2005).
(2) = Laboratory sample ID.
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.

Table C-2. PBDE Results for Stormwater (ug/L, ppb).

Site:	STMWTR_7TH						STMWTR_CLARKE						STMWTR_GREENE			
Date:	5/2/2007		5/21/2007		6/5/2007		5/2/2007		5/21/2007		6/5/2007		5/21/2007		6/5/2007	
Laboratory ID:	07184211		07214211		07234711		07184215		07214215		07234715		07214219		07234719	
PBDE-047	0.002	J	0.002	U	0.0042	NJ	0.003	U	0.002	U	0.0029	NJ	0.002	U	0.0019	U
PBDE-049	0.003	U	0.002	U	0.0019	U	0.003	U	0.002	U	0.0019	U	0.002	U	0.0019	U
PBDE-066	0.003	U	0.002	U	0.0019	U	0.003	U	0.002	U	0.0019	U	0.002	U	0.0019	U
PBDE-071	0.003	U	0.002	U	0.0019	U	0.003	U	0.002	U	0.0019	U	0.002	U	0.0019	U
PBDE-099	0.002	J	0.002	U	**0.0025**		0.003	U	0.002	U	0.0019	NJ	0.002	U	0.0019	U
PBDE-100	0.003	U	0.002	U	0.0019	U	0.003	U	0.002	U	0.0019	U	0.002	U	0.0019	U
PBDE-138	0.007	U	0.004	U	0.0038	U	0.007	U	0.004	U	0.0039	U	0.004	U	0.0038	U
PBDE-153	0.007	U	0.004	U	0.0038	U	0.007	U	0.004	U	0.0039	U	0.004	U	0.0038	U
PBDE-154	0.007	U	0.004	U	0.0038	U	0.007	U	0.004	U	0.0039	U	0.004	U	0.0038	U
PBDE-183	0.007	U	0.004	U	0.0038	U	0.007	U	0.004	U	0.0039	U	0.004	U	0.0038	U
PBDE-184	0.007	U	0.004	U	0.0038	U	0.007	U	0.004	U	0.0039	U	0.004	U	0.0038	U
PBDE-191	0.007	U	0.004	U	0.0038	U	0.007	U	0.004	U	0.0039	U	0.004	U	0.0038	U
PBDE-209	0.09	U	0.05	U	0.048	U	0.09	U	0.05	U	0.048	U	0.053	U	0.048	U
Total PBDE (ug/L)	0.004	J	0.05	U	**0.0025**		0.090	U	0.05	U	0.0048	NJ	0.053	U	0.048	U

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.
NJ = There is evidence that the analyte is present. The associated numerical result is an estimate.
Bold results are to aid the reader by distinguishing detections.

Table C-2. PBDE Results for Stormwater (ug/L, ppb) (cont'd).

Site:	STMWTR_COCHRAN						STMWTR_HOWARDBR (field replicates)									
Date:	5/2/2007		5/21/2007		6/5/2007		5/2/2007		5/21/2007		6/5/2007		6/5/2007		6/5/2007	
Laboratory ID:	07184213		07214213		07234713		07184216		07214216		07234716		07234725-1		07234726-2	
PBDE-047	0.002	U	0.002	U	**0.0059**		0.002	U	0.002	U	**0.012**		**0.008**		**0.0079**	
PBDE-049	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.0019	U	0.002	U	0.0019	U
PBDE-066	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.0019	U	0.002	U	0.0019	U
PBDE-071	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.0019	U	0.002	U	0.0019	U
PBDE-099	0.002	U	0.002	U	**0.0042**		0.002	U	0.002	U	**0.0054**		**0.0067**		**0.0054**	
PBDE-100	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.0019	U	0.002	U	0.0019	U
PBDE-138	0.005	U	0.004	U	0.0041	U	0.004	U	0.004	U	0.0039	U	0.0039	U	0.0038	U
PBDE-153	0.005	U	0.004	U	0.0041	U	0.004	U	0.004	U	0.0039	U	0.0039	U	0.0038	U
PBDE-154	0.005	U	0.004	U	0.0041	U	0.004	U	0.004	U	0.0039	U	0.0039	U	0.0038	U
PBDE-183	0.005	U	0.004	U	0.0041	U	0.004	U	0.004	U	0.0039	U	0.0039	U	0.0038	U
PBDE-184	0.005	U	0.004	U	0.0041	U	0.004	U	0.004	U	0.0039	U	0.0039	U	0.0038	U
PBDE-191	0.005	U	0.004	U	0.0041	U	0.004	U	0.004	U	0.0039	U	0.0039	U	0.0038	U
PBDE-209	0.06	U	0.05	U	0.051	U	0.05	U	0.05	U	0.048	U	0.049	U	0.048	U
Total PBDE (ug/L)	0.060	U	0.05	U	**0.0101**		0.050	U	0.050	U	**0.017**		**0.015**		**0.013**	

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.
NJ = There is evidence that the analyte is present. The associated numerical result is an estimate.
Bold results are to aid the reader by distinguishing detections.

Table C-2. PBDE Results for Stormwater (ug/L, ppb) (cont'd).

Site:	STMWTR_HSTREET						STMWTR_ERIECSO				STMWTR_LINCOLN					
Date:	5/2/2007		5/21/2007		6/5/2007		5/2/2007		6/5/2007		5/2/2007		5/21/2007		6/5/2007	
Laboratory ID:	07184212		07214212		07234712		07184223		07234723		07184214		07214214		07234714	
PBDE-047	0.002	U	0.002	U	0.002	U	**0.01**		**0.0046**		0.002	U	0.002	U	0.0019	U
PBDE-049	0.002	U	0.002	U	0.002	U	0.004	U	0.002	U	0.002	U	0.002	U	0.0019	U
PBDE-066	0.002	U	0.002	U	0.002	U	0.004	U	0.002	U	0.002	U	0.002	U	0.0019	U
PBDE-071	0.002	U	0.002	U	0.002	U	0.004	U	0.002	U	0.002	U	0.002	U	0.0019	U
PBDE-099	0.002	U	0.002	U	0.002	U	**0.013**		0.002	U	0.002	U	0.002	U	0.0019	U
PBDE-100	0.002	U	0.002	U	0.002	U	0.004	U	0.002	U	0.002	U	0.002	U	0.0019	U
PBDE-138	0.004	U	0.004	U	0.0041	U	0.008	U	0.0039	U	0.004	U	0.004	U	0.0038	U
PBDE-153	0.004	U	0.004	U	0.0041	U	0.008	U	0.0039	U	0.004	U	0.004	U	0.0038	U
PBDE-154	0.004	U	0.004	U	0.0041	U	0.008	U	0.0039	U	0.004	U	0.004	U	0.0038	U
PBDE-183	0.004	U	0.004	U	0.0041	U	0.008	U	0.0039	U	0.004	U	0.004	U	0.0038	U
PBDE-184	0.004	U	0.004	U	0.0041	U	0.008	U	0.0039	U	0.004	U	0.004	U	0.0038	U
PBDE-191	0.004	U	0.004	U	0.0041	U	0.008	U	0.0039	U	0.004	U	0.004	U	0.0038	U
PBDE-209	0.05	U	0.05	U	0.051	U	0.1	U	0.049	U	0.05	U	0.051	U	0.048	U
Total PBDE (ug/L)	0.050	U	0.050	U	0.050	U	**0.023**		**0.0046**		0.050	U	0.051	U	0.048	U

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.
NJ = There is evidence that the analyte is present. The associated numerical result is an estimate.
Bold results are to aid the reader by distinguishing detections.

Table C-2. PBDE Results for Stormwater (ug/L, ppb) (cont'd).

Site:	STMWTR_HWY291						STMWTR_MISSION				STMWTR_RIVERTON					
Date:	5/2/2007		5/21/2007		6/5/2007		5/2/2007		6/5/2007		5/2/2007		5/21/2007		6/5/2007	
Laboratory ID:	07184210		07214210		07234710		07184224		07234724		07184218		07214218		07234718	
PBDE-047	0.002	U	0.002	U	0.0019	U	0.002	U	**0.0026**		0.004	NJ	0.002	U	0.002	U
PBDE-049	0.002	U	0.002	U	0.0019	U	0.002	U	0.0019	U	0.002	U	0.002	U	0.002	U
PBDE-066	0.002	U	0.002	U	0.0019	U	0.002	U	0.0019	U	0.002	U	0.002	U	0.002	U
PBDE-071	0.002	U	0.002	U	0.0019	U	0.002	U	0.0019	U	0.002	U	0.002	U	0.002	U
PBDE-099	0.002	U	0.002	U	0.0019	U	0.002	NJ	**0.0018**	**J**	0.002	U	0.002	U	0.002	U
PBDE-100	0.002	U	0.002	U	0.0019	U	0.002	U	0.0019	U	0.002	U	0.002	U	0.002	U
PBDE-138	0.004	U	0.004	U	0.0038	U	0.005	U	0.0038	U	0.005	U	0.005	U	0.004	U
PBDE-153	0.004	U	0.004	U	0.0038	U	0.005	U	0.0038	U	0.005	U	0.005	U	0.004	U
PBDE-154	0.004	U	0.004	U	0.0038	U	0.005	U	0.0038	U	0.005	U	0.005	U	0.004	U
PBDE-183	0.004	U	0.004	U	0.0038	U	0.005	U	0.0038	U	0.005	U	0.005	U	0.004	U
PBDE-184	0.004	U	0.004	U	0.0038	U	0.005	U	0.0038	U	0.005	U	0.005	U	0.004	U
PBDE-191	0.004	U	0.004	U	0.0038	U	0.005	U	0.0038	U	0.005	U	0.005	U	0.004	U
PBDE-209	0.05	U	0.051	U	0.048	U	0.061	U	0.048	U	0.06	U	0.06	U	0.05	U
Total PBDE (ug/L)	0.050	U	0.051	U	0.048	U	0.002	NJ	**0.004**	J	0.004	NJ	0.06	U	0.06	U

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.
NJ = There is evidence that the analyte is present. The associated numerical result is an estimate.
Bold results are to aid the reader by distinguishing detections.

Table C-2. PBDE Results for Stormwater (ug/L, ppb) (cont'd).

Site:	STMWTR_SUPERIOR (field replicates)								STMWTR_UNION					
Date:	5/2/2007		5/2/2007		5/2/2007		6/5/2007		5/2/2007		5/21/2007		6/5/2007	
Laboratory ID:	07184222		07184225		07184226		07234722		07184217		07214217		07234717	
PBDE-047	0.002	U	0.002	U	0.002	U	0.0034	NJ	0.002	U	0.002	U	**0.0046**	
PBDE-049	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U
PBDE-066	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U
PBDE-071	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U
PBDE-099	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	**0.0022**	
PBDE-100	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U
PBDE-138	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.0041	U
PBDE-153	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.0041	U
PBDE-154	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.0041	U
PBDE-183	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.0041	U
PBDE-184	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.0041	U
PBDE-191	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.0041	U
PBDE-209	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.051	U	0.051	U
Total PBDE (ug/L)	0.05	U	0.05	U	0.05	U	0.003	NJ	0.05	U	0.051	U	**0.007**	

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.
NJ = There is evidence that the analyte is present. The associated numerical result is an estimate.
Bold results are to aid the reader by distinguishing detections.

Table C-2. PBDE Results for Stormwater (ug/L, ppb) (cont'd).

Site:	STMWTR_WASHINGT (field replicates)									
Date:	5/2/2007		5/21/2007		5/21/2007		5/21/2007		6/5/2007	
Laboratory ID:	07184221		07214221		07214225		07214226		07234721	
PBDE-047	**0.003**	J	0.002	U	0.002	U	0.002	U	**0.0046**	
PBDE-049	0.002	U	0.002	U	0.002	U	0.002	U	0.0019	U
PBDE-066	0.002	U	0.002	U	0.002	U	0.002	U	0.0019	U
PBDE-071	0.002	U	0.002	U	0.002	U	0.002	U	0.0019	U
PBDE-099	0.002	U	0.002	U	0.002	U	0.002	U	0.0019	U
PBDE-100	0.002	U	0.002	U	0.002	U	0.002	U	0.0019	U
PBDE-138	0.004	U	0.004	U	0.004	U	0.004	U	0.0039	U
PBDE-153	0.004	U	0.004	U	0.004	U	0.004	U	0.0039	U
PBDE-154	0.004	U	0.004	U	0.004	U	0.004	U	0.0039	U
PBDE-183	0.004	U	0.004	U	0.004	U	0.004	U	0.0039	U
PBDE-184	0.004	U	0.004	U	0.004	U	0.004	U	0.0039	U
PBDE-191	0.004	U	0.004	U	0.004	U	0.004	U	0.0039	U
PBDE-209	0.05	U	0.05	U	0.05	U	0.05	U	0.048	U
Total PBDE (ug/L)	**0.003**	J	0.05	U	0.05	U	0.05	U	**0.0046**	

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.
NJ = There is evidence that the analyte is present. The associated numerical result is an estimate.
Bold results are to aid the reader by distinguishing detections.

Table C-3. Grain Size Results for Storm-drain Sediments (%).

Site:	Hwy 291	Mission (field replicates)		Mission (lab duplicates)	
Laboratory ID:	07154210	07154224	07154224-dup	07154225-1	07154225-2
Gravel	24.2	43.1	20.4	26.1	21.4
Sand	75.4	43.3	48.2	47.5	47.4
Silt	0	11.2	21.8	17.8	21.3
Clay	0	2.3	3.5	3.1	3.5
Fines (silt/clay)	0.3	13.6	25.3	20.9	24.8

Appendix D. Glossary, Acronyms, and Abbreviations

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 designated 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.

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.

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

Acronyms and Abbreviations

CSO	Combined sewer overflow
Dioxin	Polychlorinated dibenzo-p-dioxins
dw	Dry weight
Furan	Polychlorinated dibenzofurans
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database (Ecology)
EPA	U.S. Environmental Protection Agency
MEL	Manchester Environmental Laboratory (Ecology)
PBDE	Polybrominated diphenylethers
PCB	Polychlorinated biphenyls
PEL	Probable effect level
RPD	Relative percent difference
RSD	Relative standard deviation
TCDD	Tetrachlorodibenzo-*p*-dioxin
TEQ	Total equivalent toxicity
TOC	Total organic carbon
WAC	Washington Administrative Code
ww	Wet weight