Duwamish River Basin Combined Sewer Overflow Data Report for Samples Collected from September 2007 to January 2010

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King County

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Duwamish River Basin Combined Sewer Overflow Data Report for Samples Collected from September 2007 to January 2010

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ACRONYMS

AXYS	AXYS Analytical Services Ltd.
COC	chain of custody
CSO	combined sewer overflow
CVAA	cold vapor atomic absorbance
DOC	dissolved organic carbon
EBI	Elliott Bay Interceptor
EPA	Environmental Protection Agency
FOD	frequency of detection
HPAH	high molecular weight polycyclic aromatic hydrocarbons
LPAH	low molecular weight polycyclic aromatic hydrocarbons
MDL	method detection limit
mg/L	milligrams per liter
ng/L	nanograms per liter
OPR	ongoing precision and recovery
PAHs	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyls
pg/L	micrograms per liter
RDL	reporting detection limit
SAP	sampling and analysis plan
SOP	standard operation procedures
SVOCs	semi-volatile organic compounds
TEF	toxic equivalency factors
TEQ	toxic equivalent quotient
TOC	total organic carbon
TSS	total suspended solids
µg/L	micrograms per liter

1.0 INTRODUCTION

This data report presents analytical results for combined sewer overflow (CSO) samples collected within the Duwamish River Basin. The report also briefly summarizes field and laboratory analytical methods followed in the collection of these samples. The goal of King County's CSO survey was to collect samples from the Duwamish River Basin that represent CSO conditions and to analyze these samples for polychlorinated biphenyls (PCBs), semi-volatile organic compounds (SVOCs), select metals, and conventional parameters. Resulting data will allow King County to further characterize concentrations of these parameters during CSO conditions for the Duwamish Basin. These data can be used in source control evaluations for the Duwamish Waterway and East Waterway Superfund Sites. Sampling and analysis of these samples were conducted in accordance with the *Duwamish River Basin Combined Sewer Overflow Survey Sampling and Analysis Plan* (King County 2007).

The sampling and analysis plan (SAP) outlined a survey involving the collection and analysis of in-pipe water samples from two locations, at a minimum, in the combined sewer collection system of the Duwamish River Basin. Because of the difficulty in sampling actual CSO events, samples were collected during partially- to near-full conditions of the combined sewers collection system within the Duwamish Basin to represent overflow conditions. A goal of sampling at least three events per location between September 2007 and May 2008 was established. Following development of the SAP, additional sampling locations were added including two actual CSO discharge locations, for a total of seven locations within the Duwamish River Basin. Samples were collected between September 2007 and January 2010. Samples were collected over a longer period than specified in the SAP so that more locations could be sampled and so that three to five samples per location could be collected. Samples were analyzed for PCB congeners, SVOCs, select metals, organochlorine pesticides, dioxins/furans and several conventional water quality parameters, depending on sample volume.

Field methods are summarized in Section 2 and analytical laboratory methods in Section 3. The analytical results are presented in Section 4 and validation summaries are discussed in Section 5. Supporting appendices include full data results, data validation reports, and chain of custody sheets.

2.0 FIELD COLLECTION AND SAMPLE PROCESSING METHODS

This section describes the CSO sampling locations and summarizes the collection of CSO samples including sample processing methods. The field procedures are described in greater detail in the SAP (King County 2007). Field deviations from the SAP are also presented. Copies of completed chain of custody (COC) forms used to track sample custody are presented in Appendix A.

2.1 SAMPLING STATION LOCATIONS AND SAMPLE IDENTIFICATION

CSO samples were collected from seven locations within the Duwamish Basin. Figure 1 shows the sampling location and contributing combined sewer basin associated with each overflow location. These locations were selected because they collectively represent a large portion of the Duwamish combined sewer system as well as a variety of land-use types within in the basin. Samples were collected from the combined system under conditions that represent CSOs by sampling partially- to near-full conditions of combined sewers at which CSOs may but not necessarily be discharging, At two locations, Brandon and Hanford #2, actual CSO discharges were sampled. A description of each sampling location is presented below:

- **Michigan Street Regulator:** receives flows from the east side of the Duwamish River basin that encompasses the north end of King County Airport and the industrial area of South Seattle. When there is not enough capacity in the Elliott Bay Interceptor (EBI) to accept the entire Michigan basin's flows, this regulator station releases flows to the South Michigan CSO relief structure in the Duwamish Waterway.
- **West Michigan Regulator:** receives flows from a relatively small basin on the west side of the Duwamish River basin. When there is not enough capacity in the West Duwamish Interceptor to accept all of the West Michigan basin's flows, the regulator station releases flows to the West Michigan CSO relief structure located in the Duwamish Waterway.
- **Brandon St. CSO:** receives flows from the east side of the Duwamish River basin immediately north of the Michigan system. When there is not enough capacity in the EBI to accept all of the Brandon basin's flows, the Brandon Regulator Station releases flows to the this CSO relief structure in the Duwamish Waterway
- **Duwamish Siphon Forebay:** receives flows from the west side of the Duwamish River basin which includes areas from the West Michigan system and a large portion of West Seattle region of Seattle. Flows are directed to the Duwamish Pump station through the Duwamish Siphon. Overflow relief structures are on both the west and the east side of the Duwamish Siphon in the Duwamish Waterway. The invert elevation of these relief structures is lower than critical components of the nearby Duwamish Pump Station. This elevation differential prevents the pump station from being impacted by wastewater, in the event of a catastrophic system failure. Overflows from these relief structures occur

when the Duwamish Pump Station cannot pass the full volume of the system because there is not enough capacity in the EBI.

- **Hanford #2 CSO:** receives flows from the east side of East Waterway and the Duwamish River basin and eastward over the Beacon Hill area to the Genesee and Seward Park areas of Seattle. When there is not enough capacity in the EBI to accept all of the Hanford #2 basin's flows, the Hanford #2 Regulator Station releases flows to the CSO relief structure located in the East Waterway. There is an interconnecting pipeline on Occidental Avenue between the Hanford & Lander systems to maximize system storage and this results in a large overlap in basins between Lander II and Hanford #2 (see Figure 1).
- **Lander II Regulator:** receives flows from the east side of East Waterway and the Duwamish River basin and eastward across the Beacon Hill area to the Genesee and Seward Park areas of Seattle. When there is not enough capacity in the EBI to accept all of the Lander II basin's flows, this regulator station releases flows to the Lander CSO relief structure located in the East Waterway. There is an interconnecting pipeline on Occidental Avenue between the Hanford & Lander systems to maximize system storage and this results in a large overlap in basins between Lander II and Hanford #2 (see Figure 1).
- **Kingdome Regulator:** receives flows from the south end of downtown Seattle and the east side of East Waterway just north of Lander basin. When there is not enough capacity in the EBI to accept all of the Kingdome basin's flows, this regulator station releases flows to the Connecticut Street CSO relief structure located in Elliott Bay just north of the East Waterway.

Table 2-1 lists each sampling location, its associated locator name and sample location coordinates. Samples are identified using the sample location or locator name, sample identification number and the date of collection. Each sample event per location was assigned a unique laboratory identification number by the King County Environmental Laboratory.

Table 2-1. CSO sampling locations in the Duwamish Basin.

Locator	Location	Northing	Easting
A4007	Michigan St. Regulator	202231	1270402
S070167	West Michigan Regulator	201021	1267395
063053	Brandon St. CSO	205961	1268192
A00602	Duwamish Siphon Forebay	209100	1266278
CS030	Hanford #2 CSO	214147	1267988
Lander II Regulator	Lander II Regulator	215113	1269453
Kingdome Regulator	Kingdome Regulator	219736	1270318

2.2 SAMPLE COLLECTION AND PROCESSING METHODS

Sampling was conducted by field staff of the King County Environmental Laboratory using Isco® Autosamplers. Auto samplers were automatically triggered by water depth in each sampled pipe for in-pipe samples at regulator stations and the Duwamish Siphon at the Forebay. For Hanford #2, samplers were triggered by CSO gate openings and for Brandon it was triggered by flow cresting over the overflow weir. Minimum water depth to initiate sampling was approximately 60% of full depth at the in-pipe locations. Sampling continued as long as water depths remained above the intake line or, for Brandon and Hanford #2, the CSO discharge event continued. A sample was collected every 10 minutes over a 2-hour period[1]. Depending on the location, autosamplers were either equipped with a 2.5-gallon or 5-gallon carboy (Table 2-2). The size of the carboy as well as the duration of the sampling event dictated the volume of sample collected and, thus, the number of parameters that could be analyzed per sampling event at each location. The only location with sufficient space for two autosamplers was Hanford #2, so four field duplicate[2] samples were collected over the sampling period at this location. A total of 45 CSO samples (including four field duplicates) were collected during the September 2007 to January 2010 sampling period[3]. The number of samples per location and corresponding CSO discharge events are presented in Table 2-3. As indicated in Table 2-3, not all sampling events had a corresponding CSO discharge event; e.g., no CSO discharge events occurred at West Michigan when samples were collected for this basin. Additional sample information such as the number of sample aliquots per composite sample is presented in Appendix B. For quality assurance purposes, field blanks were also collected at five of the sampling locations: Duwamish Siphon Forebay; Michigan St. Regulator; Hanford #2 CSO, Lander II Regulator, and Kingdome Regulator.

Table 2-2. Carboy size for each sample location.

Location	Carboy Size
Michigan St. Regulator	5 gal
West Michigan Regulator	2.5 gal
Brandon St. CSO	5 gal
Duwamish Siphon Forebay	2.5 gal
Hanford #2 CSO	5 gal
Lander II Regulator	5 gal
Kingdome Regulator	2.5 gal

[1] Some samples were collected over a shorter time span because the conditions or discharge event were less than two hours.

[2] Note the SAP refers to these as field replicate samples. Duplicate (or replicate) samples were collected in the same manner and time as the primary sample but collected into a separate carboy from a different auto-sampler.

[3] CSO discharge events may have occurred at a higher frequency than the number of samples collected at each location during the sampling period. However, it was not the intent of this survey to sample every CSO event at these locations.

Table 2-3. Summary of CSO samples and corresponding CSO discharge events.

Location	No. of Samples Collected	No. of corresponding CSO Discharge Events
Michigan St. Regulator	5	3
West Michigan Regulator	4[1]	0
Brandon St. CSO	7	7
Duwamish Siphon Forebay	4	1
Hanford #2 CSO	10[2]	10
Lander II Regulator	7	3
Kingdome Regulator	4	3

[1] One additional sample was collected from West Michigan Regulator on 10/13/2009 but upon review of flow conditions in the system and review of conventional analysis results, such as total suspended solids, volatile suspended solids and chemical oxygen demand, it was determined the sample represented sanitary and not CSO conditions.

[2] Four field duplicate samples were also collected.

All autosampler carboys were transported to and processed at the King County Environmental Laboratory within 24 hours of sample collection. Because auto samplers were set up to automatically initiate sampling, samples could not be refrigerated during the collection process. Upon receipt at the King County Environmental Laboratory, samples were mixed well, then split from the glass carboys into the appropriate analytical containers and preserved and held according to method specifications. All samples for dissolved metals' analysis were filtered at the King County Environmental Laboratory. With the exception of PCB and dioxin/furan congener analyses, samples were analyzed at the King County Environmental Laboratory. PCB and dioxin/furan samples[4] were shipped with ice packs to AXYS Analytical via overnight express delivery service.

2.3 FIELD DEVIATIONS FROM THE SAP

Field deviations from the SAP were as follows:

- Field blanks were not collected prior to each sampling event as specified in the SAP. However, field blanks were collected at five of the seven locations with one location having two field blanks collected.
- Carboys were not held on ice during transport to the laboratory.
- Decontamination procedures did not include acid wash for sample tubing at Hanford #2 and Lander II Regulator Station. The tubing at these locations was not removable once installed and therefore tubing was decontaminated in place and not at King County Environmental Laboratory. For the safety of field personnel, an acid wash was not

[4] Samples analyzed for dioxins/furans were from extra sample volume sent to AXYS for PCB congener analysis. The sample container, sample preservation and holding times are the same for the two analyte groups.

included in the decontamination procedures. Field blanks did not show an increase in metals at these two locations compared to other locations where tubing decontamination included acid wash. All other decontamination procedures were followed as specified in the SAP.

3.0 LABORATORY ANALYTICAL METHODS

The methods and procedures used to analyze the samples are described briefly in this section and in detail in the SAP (King County 2007). Laboratory deviations from the SAP are also presented.

Table 3-1 summarizes the analyses conducted for each CSO sample collected. The priority for sample analysis was: PCB congeners, total suspended solids (TSS), total organic carbon (TOC), dissolved organic carbon (DOC), followed by SVOCs (polycyclic aromatic hydrocarbons [PAHs] and phthalates at a minimum), metals, and other conventional parameters. Organochlorine pesticides were added to the analyte list in 2009 but could only be analyzed when sufficient volume was collected (i.e., where 5-gallon carboys could be deployed). Locations with smaller carboys (2.5 gallon) also were limited to select semi-volatile organic compounds (i.e., low-level PAHs and phthalates). Dioxin/furan congeners were analyzed in five samples in 2010 using archived samples originally collected for PCB congener analysis; 1 L of extra sample volume per sampling event at each location was delivered to AXYS when possible for PCB congener analysis. Limited analyses also occurred when the smaller volumes were collected because of the short duration of the flows high enough in the pipes to trigger sampling, or for Brandon and Hanford #2, because of the short duration of the specific CSO event. Analytical methods are identified in Table 3-2. Any modifications to methods are also included the table.

The laboratories followed the methods and procedures described in the SAP with the following exceptions:

- Mercury was initially analyzed with an MDL goal of 0.05 µg/L by EPA Method 245.1 but modified in November 2008 to achieve a detection limit of 0.005 µg/L.
- The SVOC method changed from 8270C to 8270D effective January 1, 2009 to comply with an SW846 update.
- The SVOCs target list was expanded from that specified in the SAP.
- Ammonia was specified as Standard Method SM4500-NH3-G in the SAP but was changed to Kerouel & Aminot (1997) effective January 1, 2009 to improve the method detection limit.
- Dioxin/furan congener analysis was not specified in the SAP. Analysis was performed on archived sample volume collected for PCB congener analysis. The sample container, sample preservation and holding methods are the same for both analyte groups. Seventeen dioxin/furan congeners were analyzed according to EPA Method 1613B by AXYS Analytical. There was insufficient sample to analyze a laboratory duplicate sample. All other quality control analyses (method blank, ongoing precision and recovery (OPR) sample, and surrogate spikes) were performed.

Table 3-1. Summary of analyses conducted for CSO sampling period September 2007 to January 2010.

	Sampling Location						
Parameter	**Brandon CSO**	**Duwamish Siphon Forebay**	**Michigan St. Regulator**	**Hanford #2 CSO**	**Kingdome Regulator**	**Lander Regulator**	**West Michigan Regulator**
PCB Congeners	7	4	5	10 (4 dup)	4	7	4
Total Metals	7	4	5	10 (4 dup)	3	7	3
Dissolved Metals	7	3	2	10 (4 dup)	3	6	2
Total Mercury	7	4	5	10 (4 dup)	3	7	3
Dissolved Mercury	7	2	1	8 (3 dup)	3	5	2
PAHs	7	3	5	10 (4 dup)	3	7	3
Phthalates	7	3	5	10 (4 dup)	3	7	3
Other SVOCs	7	3	5	10 (4 dup)	3	6	3
Organochlorine Pesticides	2	0	0	4 (2 dup)	0	1	0
Dioxin/furan Congeners	1	0	0	2	1	1	0
Conventionals	7	4	5	10 (4 dup)	4	7	4

Note: Conventionals can include nutrients but not always (e.g., samples for nutrient analysis were not collected at W. Michigan).

PAHs: polycyclic aromatic hydrocarbons

SVOCs: semivolatile organic compounds

Table 3-2. Analytical methods.

Analytes	Method	Comment
Polychlorinated Biphenyls (PCBs) as congeners	EPA Method 1668A	
Semivolatile Organics (SVOCs)	SW846 3520C/8270C/D	Method changed from 8270C to 8270D effective January 1, 2009 to comply with SW846 update.
Mercury by CVAA	EPA 245.1	
Metals by ICP-MS	EPA 200.8	
Organochlorine Pesticides	SW846 3520C/8081B	
Dioxin/furan congeners	EPA Method 1613B	
Ammonia-Nitrogen	SM4500-NH3-G or Kerouel & Aminot 1997	Method changed from Standard Methods to Kerouel & Aminot effective January 1, 2009 to improve method detection limit.
Nitrite-Nitrate Nitrogen	SM4500-NO3-F	
Total Nitrogen	SM4500-N-C	
Total Phosphorus	SM4500-P-B, F	
Total Alkalinity	SM2320-B	
Chloride	SM4110B CL	
Total Suspended Solids (TSS)	SM 2540-D	
Volatile Suspended Solids	SM2540-E or EPA 160.4	Equivalent methods. Change in reported method from SM2540-E to EPA 160.4 implemented effective January 1, 2009 to comply with reporting requirements of 40CFR.
Total Organic Carbon (TOC)/Dissolved Organic Carbon (DOC)	SM 5310-B	
Chemical Oxygen Demand	SM5220-D	

4.0 ANALYTICAL RESULTS

This section presents analytical results for the CSO samples and field equipment blanks. Analytical results for CSO samples are presented in Section 4.1 and field equipment blanks in Section 4.2. Complete data results for each location by sample event are presented in Appendix C for those analyses performed by the King County Environmental Laboratory. PCB and dioxin/furan congener results for each location are presented in Appendix D.

4.1 CSO RESULTS

This section presents a summary of the analytical results for CSO samples. The results are discussed separately below under each analyte group. Table 4-1 list the sample collection dates for each CSO sampling event by location.

Table 4-1. Sample IDs and collection dates by CSO location.

Location	Sample ID	Collection Date
Brandon St. CSO	L46918-5	11/06/08
Brandon St. CSO	L47190-2	01/07/09
Brandon St. CSO	L47597-5	04/02/09
Brandon St. CSO	L47992-1	05/02/09
Brandon St. CSO	L48009-4	05/04/09
Brandon St. CSO	L49487-1	10/26/09
Brandon St. CSO	L49844-1	01/04/10
Duwamish Siphon Forebay	L43913-2	09/30/07
Duwamish Siphon Forebay	L44133-2	12/02/07
Duwamish Siphon Forebay	L47597-2	04/02/09
Duwamish Siphon Forebay	L48009-1	05/05/09
Hanford #2 CSO	L44133-3	12/02/07
Hanford #2 CSO	L44133-4	12/02/07
Hanford #2 CSO	L45811-3	08/20/08
Hanford #2 CSO	L46418-3	11/04/08
Hanford #2 CSO	L46918-3	11/06/08
Hanford #2 CSO	L47597-3	04/02/09
Hanford #2 CSO	L47597-4	04/02/09
Hanford #2 CSO	L47834-1	04/12/09
Hanford #2 CSO	L47834-2	04/12/09
Hanford #2 CSO	L48009-2	05/05/09
Hanford #2 CSO	L48009-3	05/05/09
Hanford #2 CSO	L49003-1	09/06/09

Location	Sample ID	Collection Date
Hanford #2 CSO	L49556-3	11/06/09
Hanford #2 CSO	L49832-1	12/21/09
Kingdome Regulator	L46918-8	11/06/08
Kingdome Regulator	L47190-4	01/07/09
Kingdome Regulator	L48009-7	05/05/09
Kingdome Regulator	L49199-5	10/16/09
Lander II Regulator	L44912-6	06/03/08
Lander II Regulator	L45811-6	08/20/08
Lander II Regulator	L46418-6	11/04/08
Lander II Regulator	L46918-6	11/06/08
Lander II Regulator	L47834-3	04/12/09
Lander II Regulator	L47992-2	05/02/09
Lander II Regulator	L48009-5	05/04/09
Michigan Street Regulator	L43790-1	09/04/07
Michigan Street Regulator	L43913-1	09/30/07
Michigan Street Regulator	L44133-1	12/02/07
Michigan Street Regulator	L45811-1	08/19/08
Michigan Street Regulator	L46918-1	11/06/08
West Michigan Regulator	L47834-4	04/12/09
West Michigan Regulator	L48009-6	05/04/09
West Michigan Regulator	L49003-2	09/06/09
West Michigan Regulator	L49416-2	10/29/09

4.1.1 PCBs

Table 4-2 presents a summary of total PCB results for all CSO data combined and for each CSO sample location. The number of detections, the range of detected concentrations, and mean values are presented. Total PCBs are based on the sum of detected congeners. The results for each congener by sample are presented in Appendix D. Total PCB results for each individual sample are shown in Table 4-3. Total PCBs ranged from 8.01 to 455 nanograms per liter (ng/L) with a mean value of 65.2 ng/L, when all CSO data are combined. The highest concentration was measured at Brandon Street CSO and the lowest concentration at West Michigan Regulator. The highest concentration (455 ng/L) appears to be an outlier when compared to all remaining concentrations (the next highest concentration is 140 ng/L) and based on the fact this value is more than three times the standard deviation of the dataset (3*69.5 ng/L or 208.5 ng/L). The corresponding TSS in the sample with the highest total PCB concentration was 640 milligrams per liter (mg/L), which also appears to be an outlier value (see Section 4.1.5).When PCBs are reviewed by CSO sampling location, Brandon St. CSO is higher on average then other CSO locations and the West Michigan Regulator is lower on average. The other five CSO sampling

locations have similar ranges and means. If the highest concentration at Brandon Street CSO is excluded, the mean concentration is reduced from 124 ng/L to 69.7 ng/L and the mean and concentration ranges are then similar to other CSO locations except West Michigan Regulator, which is lower than all other locations.

Table 4-2. Summary of total PCB CSO data.

Locations	FOD	PCBs (ng/L) Min	Max	Mean
All CSOs Combined [1]	45/45	8.01	455	65.2
Brandon St. CSO	7/7	34.3	455	124
Duwamish Siphon Forebay	4/4	32.0	136	61.5
Michigan Street Regulator	5/5	39.8	140	77.4
Hanford #2 CSO[2]	10/10	17.7	134	63.1
Kingdome Regulator	4/4	27.8	72.1	40.8
Lander II Regulator	7/7	21.8	137	52.3
West Michigan Regulator	4/4	8.01	24.5	17.5

Total PCBs based on sum of detected PCB congeners

[1] Field duplicate results at Hanford #2 are included as individual sample results.

[2] Field duplicate results at Hanford #2 averaged prior to mean calculation

FOD = frequency of detection

Table 4-3. Concentrations of total PCBs in individual CSO samples.

Location	Sample ID	Total PCBs (ng/L)
Brandon St. CSO	L46918-5	71.7
Brandon St. CSO	L47190-2	455
Brandon St. CSO	L47597-5	132
Brandon St. CSO	L47992-1	71.6
Brandon St. CSO	L48009-4	61.8
Brandon St. CSO	L49487-1	34.3
Brandon St. CSO	L49844-1	44.4 J
Duwamish Siphon Forebay	L43913-2	32.0
Duwamish Siphon Forebay	L44133-2	34.8
Duwamish Siphon Forebay	L47597-2	136
Duwamish Siphon Forebay	L48009-1	43.2
Hanford #2 CSO	L44133-3	50.5
Hanford #2 CSO[1]	L44133-4	84.9
Hanford #2 CSO	L45811-3	47.7

Location	Sample ID	Total PCBs (ng/L)
Hanford #2 CSO	L46418-3	55.5
Hanford #2 CSO	L46918-3	134
Hanford #2 CSO	L47597-3	75.2
Hanford #2 CSO[1]	L47597-4	53.5
Hanford #2 CSO	L47834-1	17.2
Hanford #2 CSO[1]	L47834-2	18.1
Hanford #2 CSO	L48009-2	52.0 J
Hanford #2 CSO[1]	L48009-3	47.7 J
Hanford #2 CSO	L49003-1	117
Hanford #2 CSO	L49556-3	53.7
Hanford #2 CSO	L49832-1	23.1 J
Kingdome Regulator	L46918-8	31.2
Kingdome Regulator	L47190-4	31.9
Kingdome Regulator	L48009-7	72.1
Kingdome Regulator	L49199-5	27.8
Lander II Regulator	L44912-6	58.8
Lander II Regulator	L45811-6	29.0
Lander II Regulator	L46418-6	30.0
Lander II Regulator	L46918-6	137
Lander II Regulator	L47834-3	27.7
Lander II Regulator	L47992-2	61.5
Lander II Regulator	L48009-5	21.8
Michigan Street Regulator	L43790-1	70.0
Michigan Street Regulator	L43913-1	42.1
Michigan Street Regulator	L44133-1	95.3
Michigan Street Regulator	L45811-1	140
Michigan Street Regulator	L46918-1	39.8
West Michigan Regulator	L47834-4	13.2
West Michigan Regulator	L48009-6	24.5
West Michigan Regulator	L49003-2	24.2
West Michigan Regulator	L49416-2	8.01

Total PCBs based on sum of detected PCB congeners

[1] Field duplicate result

J = estimated value

4.1.2 Metals

Table 4-4 presents a summary of metals results (total and dissolved) for all CSO samples. The number of detections, the range of detected metals concentrations, mean values, and the range of method detection limits (MDLs) are presented. With the exception of mercury and silver, total metals were detected in 100 percent of the samples. Dissolved metals were detected at a lower frequency, especially dissolved concentrations of cadmium, silver and mercury. Metals results in Table 4-4 are presented in units of micrograms per liter (µg/L).

Table 4-4. Summary of metals CSO data[1]

		Detected				
Metals (µg/L)	**FOD**	**Min**	**Max**	**Mean[2]**	**Min MDL**	**Max MDL**
Arsenic, Dissolved	37/37	0.45 J	3.02	1.32	0.1	0.5
Arsenic, Total	43/43	1.24	8.06	2.47	0.1	0.5
Cadmium, Dissolved	4/37	0.059 J	0.10 J	0.033	0.05	0.1
Cadmium, Total	43/43	0.10 J	2.10	0.41	0.05	0.1
Chromium, Dissolved	37/37	0.26 J	1.05	0.59	0.2	0.4
Chromium, Total	43/43	2.1	53.8	7.47	0.2	0.4
Copper, Dissolved	37/37	1.6 J	14.7	4.4	0.4	0.4
Copper, Total	43/43	14.6	279	43.2	0.4	0.4
Iron, Dissolved	31/31	45 J	1,350	195	10	10
Iron, Total	36/36	708	16,700	3,350	10	20
Lead, Dissolved	37/37	0.23 J	1.93	0.61	0.075	0.2
Lead, Total	43/43	4.34	157	26.7	0.075	0.2
Manganese, Dissolved	37/37	5.69	179	45.0	0.05	0.2
Manganese, Total	43/43	34.3	244	93.7	0.05	0.2
Nickel, Dissolved	37/37	0.77	10.3	2.29	0.1	0.3
Nickel, Total	43/43	2.52	87.7	9.49	0.1	0.3
Silver, Dissolved	3/37	0.051 J	0.94	0.059	0.05	0.2
Silver, Total	38/43	0.051 J	4.95	0.43	0.05	0.2
Zinc, Dissolved	37/37	5.72	80.3	25.4	0.5	0.5
Zinc, Total	43/43	63.4	753	153	0.5	2.5
Mercury, Dissolved	4/31	0.0066 J	0.0435	0.0058	0.005	0.05
Mercury, Total	33/43	0.015 J	0.43	0.069	0.005	0.05

[1] Field duplicate results at Hanford #2 are included as individual sample results.

[2] Mean calculated using 1/2 MDL when analyte <MDL.

FOD = frequency of detection

MDL= method detection limit

Results for total arsenic, total copper, total lead, total zinc, and total mercury are also summarized by CSO in Table 4-5.Total arsenic concentrations ranged from 1.24 to 8.06 µg/L with a mean of 2.47 µg/L. The lowest concentration was measured at the Brandon Street CSO and the highest at Duwamish Siphon Forebay. When arsenic concentrations are reviewed by CSO sampling location, they were generally similar, with the exception of Duwamish Siphon Forebay, which had a slightly higher mean total arsenic concentration than other sampling locations (Table 4-5).

Table 4-5. Summary of metals data by CSO sampling location[1]

Location	FOD	Detected Min	Detected Max	Mean[2]
Arsenic, Total (µg/L)				
All CSOs Combined [3]	43/43	1.24	8.06	2.47
Brandon St. CSO	7/7	1.24	6.97	2.79
Duwamish Siphon Forebay	4/4	2.4 J	8.06	4.50
Michigan Street Regulator	5/5	1.4 J	2.92	2.12
Hanford #2 CSO[4]	10/10	1.7 J	2.99	2.31
Kingdome Regulator	3/3	1.85	2.74	2.33
Lander II Regulator	7/7	1.33	2.67	1.92
West Michigan Regulator	3/3	1.30	3.71	2.27
Copper, Total (µg/L)				
All CSOs Combined [3]	43/43	14.6	279	43.2
Brandon St. CSO	7/7	24.9	279	80.0
Duwamish Siphon Forebay	4/4	51.3	80.7	66.3
Michigan Street Regulator	5/5	14.9	76.3	39.7
Hanford #2 CSO[4]	10/10	14.9	41.1	26.0
Kingdome Regulator	3/3	42.9	76.1	59.1
Lander II Regulator	7/7	22.8	40.4	28.1
West Michigan Regulator	3/3	17.4	65.6	35.9
Lead, Total (µg/L)				
All CSOs Combined [3]	43/43	4.34	157	26.7
Brandon St. CSO	7/7	14.0	157	45.0
Duwamish Siphon Forebay	4/4	14.2	96.4	61.5
Michigan Street Regulator	5/5	13.6	49.9	27.0
Hanford #2 CSO[4]	10/10	4.70	24.5	14.0

Location	FOD	Detected Min	Detected Max	Mean[2]
Kingdome Regulator	3/3	19.5	56.0	34.7
Lander II Regulator	7/7	8.24	17.1	12.0
West Michigan Regulator	3/3	12.0	52.5	25.6
Zinc, Total (µg/L)				
All CSOs Combined [3]	43/43	63.4	753	153
Brandon St. CSO	7/7	100	753	253
Duwamish Siphon Forebay	4/4	107	326	218
Michigan Street Regulator	5/5	88.3	244	156
Hanford #2 CSO[4]	10/10	69.4	153	111
Kingdome Regulator	3/3	134	258	192
Lander II Regulator	7/7	70.9	174	105
West Michigan Regulator	3/3	63.4	215	121
Mercury, Total (µg/L)				
All CSOs Combined [3]	33/43	0.015 J	0.43	0.069
Brandon St. CSO	6/7	0.017	0.43	0.092
Duwamish Siphon Forebay	3/4	0.051 J	0.164	0.080
Michigan Street Regulator	3/5	0.039	0.256	0.091
Hanford #2 CSO[4]	7/10	0.017	0.113	0.054
Kingdome Regulator	3/3	0.039	0.051	0.046
Lander II Regulator	5/7	0.016	0.287	0.072
West Michigan Regulator	3/3	0.015 J	0.098	0.047

[1] Select analytes summarized; all data presented in Appendix C.

[2] Mean calculated using 1/2 MDL when analyte <MDL.

[3] Field duplicate results at Hanford #2 are included as individual sample results.

[4] Field duplicate results at Hanford #2 averaged prior to mean calculation

FOD = frequency of detection

Total copper concentrations ranged from 14.6 to 279 µg/L with a mean of 43.2 µg/L. The lowest concentrations were measured at Hanford #2 CSO and Michigan Street Regulator and the highest at Brandon St. CSO. When copper concentrations are reviewed by CSO sampling location, they have similar ranges. The mean concentrations are slightly higher at Duwamish Siphon Forebay, Kingdome Regulator and Brandon St. CSO, which had highest mean concentration, compared to other locations (Table 4-5). However, if the 279 µg/L total copper concentration is excluded, concentrations at Brandon St. CSO are similar to other locations (Appendix C).

Total lead concentrations ranged from 4.34 to 157 µg/L with a mean of 26.7 µg/L. The lowest concentration was measured at Hanford #2 CSO and the highest at Brandon St. CSO. When lead concentrations are reviewed by CSO sampling location, they tended to have similar ranges and means with the exception of Brandon St. CSO and Duwamish Siphon Forebay, which both had higher mean concentrations (Table 4-5). However, if the 157µg/L total lead concentration is excluded, concentrations at Brandon St. CSO are lower on average than Duwamish Siphon Forebay and similar to other locations (Appendix C).

Total zinc concentrations ranged from 63.4 to 753 µg/L with a mean of 153 µg/L. The lowest concentration was measured at the West Michigan Regulator and the highest at Brandon St. CSO. Total zinc concentrations tend to be more variable by location than other metals (Table 4-5). The highest concentration on average is still observed at Brandon St. CSO; however, when this concentration (753 µg/L) is removed, the data are similar to Duwamish Siphon Forebay, Michigan Street Regulator and Kingdome Regulator. The lowest concentrations on average are found at Hanford #2 CSO, Lander II Regulator and West Michigan Regulator.

Total mercury was detected in 33 of 43 samples. Detected total mercury concentrations ranged from 0.015 to 0.43 µg/L with a mean of 0.069 µg/L, based on all samples. The lowest detected concentration was measured at West Michigan Regulator and the highest at Brandon St. CSO. When mercury concentrations are reviewed by CSO sampling location, they tended to have similar ranges and means.

The sample with the highest copper, lead and zinc concentrations also had the highest TSS concentration, all of which appear to be outlier values when compared to the remaining data for each metal and the fact each is more than three times the standard deviation of the dataset[5]. This is the same sample with the highest PCB concentration. This sample was collected from the Brandon Street CSO.

4.1.3 Semi-volatile Organic Compounds

Table 4-6 presents a summary of SVOC results for all CSO samples. The number of detections, the range of detected concentrations, mean values, and the range of MDLs are presented. SVOC results are included in Table 4-6 for only those compounds detected in at least one sample. Results for all SVOCs including the non-detected analytes are included in Appendix C. Up to 76 SVOCs were analyzed in CSO samples[6] and of these 37 were detected at least once. Unlike total metals, where the highest concentrations were associated with one sampling event at the Brandon St. CSO, maximum concentrations of individual SVOCs were measured at different CSO sampling locations and during different events. SVOC results in Table 4-6 are presented in units of µg/L.

[5] The standard deviation for each dataset is as follows: copper-41.7 µg/L; lead-29.1 µg/L; and zinc 112.4 µg/L.

[6] CSO samples were first analyzed for approximately 32 SVOCs as outlined in the SAP and then full SVOC analysis was added for a total of 76 SVOCs. This and the carboy size at a sampling location results in varying number of sample counts for different SVOC compounds.

Table 4-6. Summary of semi-volatile organic compound CSO data[1,]

SVOCs (µg/L)	FOD	Detected Min	Detected Max	Mean[3]	Min MDL	Max MDL[4]
Phthalates						
Benzyl Butyl Phthalate	39/42	0.257	4.89	0.896	0.025	2.4
Bis(2-Ethylhexyl)Phthalate	13/41	1.51	45	5.35	0.024	10.2
Diethyl Phthalate	40/42	0.246	3.87	1.12	0.013	1.2
Dimethyl Phthalate	19/42	0.0678	4.54	0.230	0.013	0.24
Di-N-Butyl Phthalate	18/42	0.121	0.841	0.227	0.024	0.83
Di-N-Octyl Phthalate	6/42	0.512	2.18	0.193	0.013	0.24
PAHs						
2-Methylnaphthalene	35/42	0.028	2.4	0.274	0.005	0.24
Acenaphthene	13/42	0.0286	0.125	0.026	0.005	0.094
Acenaphthylene	2/42	0.0284	0.0839	0.0093	0.005	0.094
Anthracene	18/42	0.018	0.245	0.035	0.005	0.094
Benzo(a)anthracene	32/42	0.0187	0.37	0.076	0.005	0.094
Benzo(a)pyrene	20/42	0.0363	0.37	0.077	0.005	0.094
Benzo(b)fluoranthene	22/42	0.0236	0.506	0.083	0.005	0.094
Benzo(g,h,i)perylene	18/42	0.0226	0.257	0.049	0.005	0.094
Benzo(k)fluoranthene	23/42	0.0209	0.33	0.072	0.005	0.094
Chrysene	32/42	0.023	0.497	0.103	0.005	0.094
Dibenzo(a,h)anthracene	9/42	0.009	0.0925	0.016	0.005	0.094
Fluoranthene	35/42	0.0233	0.687	0.146	0.005	0.094
Fluorene	21/42	0.0279	0.273	0.058	0.005	0.094
Indeno(1,2,3-Cd)Pyrene	19/42	0.0188	0.212	0.044	0.005	0.094
Naphthalene	33/42	0.0281	1.29	0.167	0.005	0.094
Phenanthrene	39/42	0.0544	0.848	0.209	0.005	0.094
Pyrene	37/42	0.025	0.868 J	0.193	0.005	0.094
Total LPAH[5]	40/42	0.071	4.67	0.748	N/A	N/A
Total HPAH[5]	38/42	<MDL	4.11	0.825	N/A	N/A
Other SVOCs						
1,4-Dichlorobenzene	40/41	0.0811	534	64.3	0.0047	1.2
1,2,4-Trichlorobenzene	1/17	0.0631	0.0631	0.028	0.024	0.24

SVOCs (µg/L)	FOD	Detected Min	Detected Max	Mean[3]	Min MDL	Max MDL[4]
2,4-Dichlorophenol	3/17	0.149	0.175	0.074	0.047	0.47
2-Methylphenol	7/17	0.0627 J	2.07 J	0.207	0.024	0.24
4-Methylphenol	31/41	0.201	200	12.6	0.047	2.4
Benzoic Acid	16/16	1.19	270	60.8	0.24	12
Benzyl Alcohol	27/38	0.058 J	27.5 J	2.42	0.047	0.94
Bis(2-ethylhexyl)adipate	5/22	0.257	0.356	0.153	0.047	0.60
Bisphenol A	17/22	0.18	31.5	2.21	0.12	0.13
Carbazole	3/25	0.0501	0.124	0.030	0.0094	0.24
Dibenzofuran	5/24	0.0251	0.149	0.031	0.0094	0.24
Pentachlorophenol	16/41	0.10	1.28 J	0.543	0.094	12
Phenol	32/41	0.052	26.3 J	2.77	0.024	1.2
Total 4-Nonylphenol	19/22	0.755	12.6	3.53	0.047	0.05

[1] Table only includes analytes that were detected in at least one sample.

[2] Field duplicate results at Hanford #2 are included as individual sample results.

[3] Mean calculated using 1/2 MDL when analyte <MDL. Two samples were not included in the calculation of the mean when the individual parameter result was <MDL. These two samples were analyzed at a 1:50 dilution, resulting in numeric MDLs that were 50 times higher than normal.

[4]Max MDL does not include elevated MDL values from two samples analyzed at a 1:50 dilution.

[5]Counted as detected if at least one individual PAH in the sum was detected.

LPAH and HPAH based on sum of detected PAH compounds

FOD = frequency of detection

MDL= method detection limit

LPAH = Low molecular weight polycyclic aromatic hydrocarbons

HPAH = High molecular weight polycyclic aromatic hydrocarbons

Results for select SVOCs are also summarized by CSO in Table 4-7. Two low-molecular-weight and two high-molecular-weight PAHs were selected, as were Total LPAH and Total HPAH. One phenolic and one phthalate compound that had higher frequencies of detections were selected and 1, 4-dichlorobenzene was selected because it was detected in 40 out of 41 samples and showed distinct differences between one CSO and other CSO sampling locations.

Table 4-7. Summary of semi-volatile organic compounds data by CSO sampling location[12]

Location	FOD	Detected Min	Detected Max	Mean[2]
Polycyclic Aromatic Hydrocarbons				
Fluoranthene (µg/L)				
All CSOs Combined [3]	35/42	0.023	0.687	0.146
Brandon St. CSO	7/7	0.050	0.687	0.283
Duwamish Siphon Forebay	3/3	0.086 J	0.265	0.155
Michigan Street Regulator	5/5	0.070	0.641	0.196
Hanford #2 CSO[4]	8/10	0.046	0.232	0.108
Kingdome Regulator	1/3	0.521	0.521	0.177
Lander II Regulator	6/7	0.044	0.099	0.052
West Michigan Regulator	2/3	0.023	0.194	0.074
Pyrene (µg/L)				
All CSOs Combined [3]	37/42	0.025	0.868	0.193
Brandon St. CSO	7/7	0.103	0.793	0.385
Duwamish Siphon Forebay	3/3	0.072	0.330	0.178
Michigan Street Regulator	4/5	0.065	0.454	0.147
Hanford #2 CSO[4]	9/10	0.025	0.278	0.151
Kingdome Regulator	3/3	0.171	0.868 J	0.420
Lander II Regulator	6/7	0.065	0.112	0.070
West Michigan Regulator	2/3	0.042	0.238	0.095
Naphthalene (µg/L)				
All CSOs Combined [3]	33/42	0.0281	1.29	0.167
Brandon St. CSO	6/7	0.028	0.122	0.054
Duwamish Siphon Forebay	3/3	0.086	0.687	0.371
Michigan Street Regulator	5/5	0.037	0.302	0.159
Hanford #2 CSO[4]	6/10	0.083	0.364	0.117
Kingdome Regulator	3/3	0.307	1.29	0.665
Lander II Regulator	5/7	0.043	0.445	0.101
West Michigan Regulator	3/3	0.041	0.082	0.056
Phenanthrene (µg/L)				
All CSOs Combined [3]	39/42	0.054	0.848	0.209

Location	FOD	Detected Min	Detected Max	Mean[2]
Brandon St. CSO	7/7	0.091	0.623	0.266
Duwamish Siphon Forebay	3/3	0.123	0.250	0.166
Michigan Street Regulator	5/5	0.059	0.848	0.259
Hanford #2 CSO[4]	9/10	0.126	0.419	0.210
Kingdome Regulator	3/3	0.231	0.594	0.460
Lander II Regulator	7/7	0.063	0.164	0.099
West Michigan Regulator	2/3	0.054	0.134	0.064
Total HPAH [5] (µg/L)				
All CSOs Combined [3]	38/42	<MDL	4.11	0.83
Brandon St. CSO	7/7	0.31	4.11	1.74
Duwamish Siphon Forebay	3/3	0.65	1.57	0.99
Michigan Street Regulator	5/5	0.13	2.62	0.78
Hanford #2 CSO[4]	9/10	0.09	1.04	0.53
Kingdome Regulator	3/3	0.50	3.48	1.60
Lander II Regulator	6/7	<MDL	0.40	0.22
West Michigan Regulator	2/3	<MDL	1.37	0.50
Total LPAH [5] (µg/L)				
All CSOs Combined [3]	40/42	0.07	4.67	0.74
Brandon St. CSO	7/7	0.12	1.16	0.51
Duwamish Siphon Forebay	3/3	0.45	1.36	0.93
Michigan Street Regulator	5/5	0.13	2.00	0.77
Hanford #2 CSO[4]	9/10	0.19	1.62	0.72
Kingdome Regulator	3/3	0.70	4.67	2.44
Lander II Regulator	7/7	0.07	1.16	0.45
West Michigan Regulator	3/3	0.08	0.32	0.19
Other Semi-volatile Organic Compounds				
1,4-Dichlorobenzene (µg/L)				
All CSOs Combined [3]	40/41	0.081	534	64.3
Brandon St. CSO	7/7	0.115	0.783	0.272
Duwamish Siphon Forebay	3/3	0.506	1.03	0.722
Michigan Street Regulator	5/5	0.081	0.848	0.291
Hanford #2 CSO[4]	10/10	78.8	534	183

Location	FOD	Detected Min	Detected Max	Mean[2]
Kingdome Regulator	2/3	0.152	0.451	0.202
Lander II Regulator	6/6	0.212	0.577	0.435
West Michigan Regulator	3/3	0.266	3.15	1.37
Phenol (µg/L)				
All CSOs Combined [3]	32/41	0.05	26.3[6]	2.77
Brandon St. CSO	5/7	0.36	1.52	0.62
Duwamish Siphon Forebay	2/3	1.16	1.18	0.79
Michigan Street Regulator	4/5	0.05	0.48	0.21
Hanford #2 CSO[4]	9/10	1.40	24.7 J	5.52
Kingdome Regulator	3/3	0.12	6.25	2.55
Lander II Regulator	3/6	0.35	3.29	0.69
West Michigan Regulator	2/3	0.64	1.38	0.68
Benzyl Butyl Phthalate (µg/L)				
All CSOs Combined [3]	39/42	0.257	4.89[6]	0.896
Brandon St. CSO	7/7	0.334	1.04	0.668
Duwamish Siphon Forebay	3/3	0.468	0.876	0.688
Michigan Street Regulator	4/5	0.257	0.847	0.565
Hanford #2 CSO[4]	9/10	0.395	4.80	1.15
Kingdome Regulator	3/3	0.408	1.41	0.896
Lander II Regulator	6/7	0.338	1.12	0.635
West Michigan Regulator	3/3	0.354	0.393	0.370

LPAH and HPAH based on sum of detected PAH compounds

[1] Select analytes summarized; all data presented in Appendix C.

[2] Mean calculated using 1/2 MDL when analyte <MDL. Two samples were not included in the calculation of the mean when the individual parameter result was <MDL. These two samples were analyzed at a 1:50 dilution, resulting in numeric MDLs that were 50 times higher than normal.

[3] Field duplicate results at Hanford #2 are included as individual sample results.

[4] Field duplicate results at Hanford #2 averaged prior to mean calculation

[5] Counted as detected if at least one individual PAH in the sum was detected.

[6] Maximum concentration is based on an individual Hanford #2 CSO field duplicate sample prior to averaging field duplicates.

FOD = frequency of detection

LPAH = Low molecular weight polycyclic aromatic hydrocarbons

HPAH = High molecular weight polycyclic aromatic hydrocarbons

MDL= method detection limit

Fluoranthene was detected in 35 of 42 samples with detected concentrations ranging from 0.023 to 0.687 µg/L and a mean concentration of 0.146 µg/L. The lowest detected concentration was measured at the West Michigan Regulator and the highest at Brandon St. CSO. Fluoranthene concentrations tended to be more variable by location (Table 4-7). The highest mean concentration was observed at Brandon St. CSO with the lowest mean concentrations observed at the Lander II and West Michigan Regulators.

Pyrene was detected in 37 of 42 samples with detected concentrations ranging from 0.025 to 0.868 µg/L and a mean concentration of 0.193 µg/L. The lowest detected concentration was measured at Hanford #2 CSO and the highest at the Kingdome Regulator. When pyrene concentrations were reviewed by CSO sampling location, they tended to have similar ranges and means with the exception of Brandon St. CSO and the Kingdome Regulator, which had higher mean concentrations (Table 4-7).

Naphthalene was detected in 33 of 42 samples with detected concentrations ranging from 0.028 to 1.29 µg/L and a mean concentration of 0.167 µg/L. The highest concentration was measured at Kingdome Regulator and the lowest detected concentration at Brandon St. CSO. When naphthalene concentrations were reviewed by CSO sampling location, data tended to be similar on average for Michigan St. Regulator, Hanford #2 CSO, and Lander II Regulator (Table 4-7). Duwamish Siphon Forebay and Kingdome Regulator were higher on average and Brandon St. CSO and West Michigan Regulator lower.

Phenanthrene was detected in 39 of 42 samples with detected concentrations ranging from 0.054 to 0.848 µg/L and a mean concentration of 0.209 µg/L. The lowest detected concentration was measured at the West Michigan Regulator and the highest concentration was measured at the Michigan St. Regulator. Phenanthrene concentrations tended to be more variable by location (Table 4-7).

Total LPAHs were calculated for all 40 of 42 samples and total HPAHs for 38 of 42 samples. Total LPAH concentrations ranged from 0.070 to 4.67 µg/L and total HPAH concentrations ranged from <MDL to 4.11 µg/L; mean concentrations were 0.74 µg/L for total LPAHs and 0.83 µg/L for total HPAHs. Total LPAHs tended to have similar ranges for each CSO location with the exception of Kingdome Regulator, which had higher concentrations when compared to all other LPAH data. Total HPAHs tended to be higher at Brandon St. CSO and the Kingdome Regulator and generally similar at other CSO sampling locations.

1,4-Dichlorobenzene was detected in 40 of 41 samples at concentrations ranging from 0.081 to 534 µg/L with a mean concentration of 64.3 µg/L. The lowest concentration was measured at Michigan St. Regulator and the highest at Hanford #2 CSO. All locations but Hanford #2 CSO had similar ranges of 1,4-dichlorobenzene (Table 4-7). Concentrations at Hanford #2 CSO were consistently one to two orders of magnitude higher than at all other locations. Mean concentrations ranged from 0.202 to 1.37 µg/L at all CSO locations except Hanford #2 CSO, which had mean concentration of 183 µg/L, 1,4-Dichlorobenzene is the only chemical that appears to consistently be found at concentrations more than 100 times greater at one CSO location compared to other locations sampled.[7]

[7] The major source of 1,4-dichlorobenzene to the Hanford #2 CSO is believed to have been identified and the product use that was the cause was discontinued in May 2010.

Phenol was detected in 32 of 41 samples with detected concentrations ranging from 0.052 to 26.3 µg/L and a mean concentration of 2.77 µg/L. The lowest detected concentration was measured at Michigan St. Regulator and the highest concentration at Hanford #2 CSO. Phenol had similar concentration ranges at all CSO locations except Hanford #2 CSO and the Kingdome Regulator, where mean concentrations were higher than at other locations (Table 4-7).

Benzyl butyl phthalate was detected in 39 of 42 samples with detected concentrations ranging from 0.257 to 4.89 µg/L and a mean concentration of 0.896 µg/L. The lowest detected concentration was measured at Michigan St. Regulator and the highest concentration at Hanford #2 CSO. Benzyl butyl phthalate had similar concentration ranges at all CSO locations except for one sampling event at Hanford #2 CSO where concentrations were approximately two to twenty times higher than all other samples (Table 4-7).

4.1.4 Organochlorine Pesticides

Organochlorine pesticides were not originally included as analytes in the CSO SAP but were added in 2009. A total of seven samples (including two field duplicate samples at Hanford #2 CSO) were analyzed for organochlorine pesticides. In all samples, organochlorine pesticides were not detected at MDLs ranging from 0.024 to 0.24 µg/L. Appendix C presents the pesticide data including MDLs.

4.1.5 Dioxins/Furans

Table 4-8 presents total dioxins/furans results for each CSO sample location. Total dioxins/furans are based on the sum of 17 congeners expressed as toxic equivalent quotient (TEQ). TEQs are calculated using World Health Organization toxic equivalency factor (TEF) values for mammals (Van den Berg et al. 2006). When a congener is reported as not detected, 1/2 the detection limit is used along with the TEF to estimate the TEQ for that congener. The results for each dioxin/furan congener by sample are presented in Appendix D. Total dioxins/furans ranged from 4.3 to 11.8 picograms TEQ per liter (pg TEQ/L) with a mean value of 9.16 pg TEQ/L when the five CSO sample data are combined. The lowest concentration was measured at Lander II Regulator Station and the highest concentrations were at Brandon Street CSO and Hanford #2 CSO.

Table 4-8. Concentrations of total dioxins/furans in individual CSO samples

Location	Sample ID	Total dioxin/furan (pg TEQ/L)
Brandon St. CSO	L49487-1	11.2 J
Hanford #2 CSO	L48009-2	11.8 J
Hanford #2 CSO	L49003-1	11 J
Kingdome Regulator	L49199-5	7.5 J
Lander II Regulator	L47992-2	4.3 J

Note: mean concentration of the five samples is 9.16 pg TEQ/L.

TEQ = toxic equivalent quotient
J = estimated value

4.1.6 Conventional Parameters

Table 4-9 presents a summary of conventional parameters results for all CSO samples. The frequency of detection, range of detected concentrations, mean values, and the range of method detection limits (MDLs) are presented. Conventional parameters summarized in Table 4-9 include total suspended solids, dissolved and total organic carbon, ammonia, nitrite + nitrate nitrogen, total nitrogen, total phosphorus, and total alkalinity. A subset of these parameters is summarized by CSO in Table 4-10. Samples were also analyzed for volatile suspended solids, chemical oxygen demand, and chloride. Results for these other conventional parameters are included in Appendix C.

Table 4-9. Summary of conventional CSO data[1]

		Detected				
Conventionals (mg/L)	**FOD**	**Min**	**Max**	**Mean[2]**	**Min MDL**	**Max MDL**
Total Suspended Solids	45/45	34.0	640	131	2	20
Dissolved Organic Carbon	45/45	3.57	610	30.5	0.5	50
Total Organic Carbon	45/45	12.9	625	54.4	0.5	50
Ammonia Nitrogen	42/42	0.245	14.2	4.09	0.005	1
Nitrite + Nitrate Nitrogen	37/42	0.014	1.24	0.395	0.01	0.1
Total Nitrogen	42/42	1.08	23.4	8.08	0.05	1.5
Total Phosphorus	42/42	0.192	4.75	1.55	0.005	0.15
Total Alkalinity	40/40	13.3	174	49.2	1	1

[1] Field duplicate results at Hanford #2 are included as individual sample results.

[2] Mean calculated using 1/2 MDL when analyte <MDL.

FOD = frequency of detection

MDL= method detection limit

Table 4-10. Summary of conventional data by CSO sampling location[1]

		Detected		
Location	**FOD**	**Min**	**Max**	**Mean[2]**
Total Suspended Solids (mg/L)				
All CSOs Combined [3]	45/45	34.0	640	131
Brandon St. CSO	7/7	61.5	640	199
Duwamish Siphon Forebay	4/4	97.0	320	188
Michigan Street Regulator	5/5	43.5	227	130
Hanford #2 CSO[4]	10/10	36.4	156	81.7
Kingdome Regulator	4.4	95.6	241	145
Lander II Regulator	7/7	38.0	109	71.6

Location	FOD	Detected Min	Detected Max	Mean[2]
West Michigan Regulator	4/4	102	348	224
Dissolved Organic Carbon (mg/L)				
All CSOs Combined [3]	45/45	3.57	610	30.5
Brandon St. CSO	7/7	3.57	27.7	12.5
Duwamish Siphon Forebay	4/4	8.02	16.1	11.7
Michigan Street Regulator	5/5	7.06	15.0	10.4
Hanford #2 CSO[4]	10/10	5.93	610	80.5
Kingdome Regulator	4/4	7.28	22.2	12.2
Lander II Regulator	7/7	7.91	68.6	21.1
West Michigan Regulator	4/4	11.2	14.1	12.8
Total Organic Carbon (mg/L)				
All CSOs Combined [3]	45/45	12.9	625	54.4
Brandon St. CSO	7/7	12.9	81.0	35.9
Duwamish Siphon Forebay	4/4	29.1	62.9	42.5
Michigan Street Regulator	5/5	21.9	60.7	37.8
Hanford #2 CSO[4]	10/10	17.4	625	97.5
Kingdome Regulator	4/4	30.2	45.0	36.9
Lander II Regulator	7/7	20.6	92.2	43.5
West Michigan Regulator	4/4	34.7	55.7	47.8
Total Nitrogen (mg/L)				
All CSOs Combined [3]	42/42	1.08	23.4[5]	8.08
Brandon St. CSO	7/7	1.08	4.94	3.29
Duwamish Siphon Forebay	4/4	5.69	12.7	9.24
Michigan Street Regulator	5/5	3.00	8.33	5.71
Hanford #2 CSO[4]	10/10	5.33	22.9	10.5
Kingdome Regulator	3/3	2.68	4.98	3.81
Lander II Regulator	7/7	3.92	13.9	7.59
West Michigan Regulator	2/2	12.0	17.2	14.6
Total Phosphorus (mg/L)				
All CSOs Combined [3]	42/42	0.192	4.75[5]	1.55
Brandon St. CSO	7/7	0.19	1.85	0.86
Duwamish Siphon Forebay	4/4	0.98	4.02	2.08
Michigan Street Regulator	5/5	0.51	2.03	1.18

Location	FOD	Detected Min	Detected Max	Mean[2]
Hanford #2 CSO[4]	10/10	0.71	4.37	1.82
Kingdome Regulator	3/3	0.74	1.15	0.91
Lander II Regulator	7/7	0.64	2.26	1.40
West Michigan Regulator	2/2	2.24	3.47	2.36

[1] Select analytes summarized; all data presented in Appendix C.

[2] Mean calculated using 1/2 MDL when analyte <MDL.

[3] Field duplicate results at Hanford #2 are included as individual sample results.

[4] Field duplicate results at Hanford #2 averaged prior to mean calculation

[5] Maximum concentration is based on an individual Hanford #2 CSO field duplicate sample prior to averaging field duplicates

FOD = frequency of detection

Total suspended solids (TSS) concentrations ranged from 34 to 640 mg/L with a mean of 131 mg/L. The lowest concentration was measured at Hanford #2 CSO and the highest at the Brandon Street CSO. When TSS concentrations are reviewed by CSO sampling location, the West Michigan Regulator had higher mean concentrations compared to other locations. Mean concentrations were lowest at Hanford #2 CSO and Lander II regulator when compared to other locations (Table 4-10). The sample with the highest TSS concentration appears to be an outlier when compared to remaining TSS concentrations and the fact that it is more than three times the standard deviation of the dataset (3*108.5 mg/L or 325.6 mg/L). This sample also had the highest metals and total PCB concentrations.

Total organic carbon (TOC) ranged from 12.9 to 625 mg/L and dissolved organic carbon (DOC) ranged from 3.57 to 610 mg/L; mean concentrations were 54.4 mg/L for TOC and 30.5 mg/L for DOC. The highest concentrations of TOC and DOC were measured at Hanford #2 CSO and the lowest at Brandon St. CSO. TOC and DOC tended to have similar ranges for each CSO location with the exception of Hanford #2 CSO and Lander II Regulator (Table 4-10). DOC data for Lander II Regulator was slightly higher on average than other CSO locations due to one sample; all other DOC samples fell within the range of other CSO locations. The maximum concentration of both TOC and DOC at Hanford #2 CSO appear to be outliers. These values are much higher in concentrations than the rest of the TOC and DOC data for all CSOs (Appendix C) and they are more than three times the standard deviation for each dataset[8].

Total nitrogen ranged from 1.08 to 23.4 mg/L and total phosphorus ranged from 0.192 to 4.75 mg/L; mean concentrations were 8.08 mg/L for total nitrogen and 1.55 mg/L for total phosphorus. The highest concentrations of total nitrogen and total phosphorus were measured at Hanford #2 CSO and the lowest at Brandon St. CSO (Table 4-10). While total nitrogen tended to be lower on average at Brandon St. CSO and Kingdome Regulator compared to other locations, total phosphorus had somewhat similar ranges and means for each CSO location.

[8] The standard deviations for TOC and DOC are 89.9 mg/L and 89.7 mg/L, respectfully.

4.2 FIELD BLANK RESULTS

This section presents a summary of the analytical chemistry results for field blanks. Table 4-11 lists the sample collection dates and locations for each field blank. All field blanks were analyzed for total metals, SVOCs including phthalates and PAHs, and PCB congeners. Table 4-12 shows results for detected analytes in field blank samples. All field blank results can be found in Table C-11, Appendix C and Table D-12, Appendix D.

Table 4-11. Field blank sample IDs and collection locations and dates

Locator	Location	Sample ID	Collection Date
A00602	Duwamish Siphon Forebay	L42798-1	05/24/07
A4007	Michigan St. Regulator	L43912-1	09/13/07
A00602	Duwamish Siphon Forebay	L44132-1	10/19/07
CS030	Hanford #2 CSO	L44913-1	01/28/08
Lander II	Lander II Regulator	L45805-1	06/05/08
Kingdome	Kingdome Regulator	L48336-1	06/11/09

Table 4-12. Field blank results for detected analytes.

	Sample ID					
Analyte	**L42798-1**	**L43912-1**	**L44132-1**	**L44913-1**	**L45805-1**	**L48336-1**
Metals (µg/L)						
Cadmium, Total	ND	ND	0.39 J	ND	ND	ND
Chromium, Total	ND	ND	0.48 J	ND	ND	ND
Copper, Total	ND	ND	0.4 J	ND	ND	ND
Manganese, Total	ND	ND	1.26	ND	0.22 J	0.19 J
Zinc, Total	2.2 J	0.63 J	1.7 J	ND	ND	0.74 J
SVOCs (µg/L)						
Benzyl Butyl Phthalate	ND	ND	0.103	ND	ND	ND
Bis(2-Ethylhexyl)Phthalate	ND*	0.0502	ND*	ND*	7.91	ND*
Diethyl Phthalate	0.193	0.147	0.186	0.371	0.135	ND*
Dimethyl Phthalate	ND	ND	ND	ND	0.108	ND
Di-N-Butyl Phthalate	ND	0.0962	ND*	ND*	ND*	ND*
Naphthalene	ND	ND	ND	ND*	0.0269	ND

Analyte	Sample ID					
	L42798-1	L43912-1	L44132-1	L44913-1	L45805-1	L48336-1
PCBs (ng/L)						
Total PCBs	0.012	0.151	0.199	0.664	1.13	0.059

ND = not detected

J = Estimated value – detected value is between the method detection limit and quantitation limit.

* = Detected in both field blank and method blank; qualified as not detected based on validation findings (see Appendix E).

Most analytes were not detected in the field blanks. Overall, field blanks had detections of the same compounds often found in method blanks: phthalates, zinc, and select PCB congeners. Zinc was detected in four field blanks, two collected at the Duwamish Siphon Forebay and one each collected at the Michigan St. Regulator and Kingdome Regulator stations. Manganese was detected in field blanks collected at the Duwamish Siphon Forebay and the Lander II Regulator and Kingdome Regulator stations (Table 4-12). Cadmium, chromium, and copper were detected in one field blank collected at Duwamish Siphon Forebay. Diethyl phthalate was detected in five out of six field blank samples, while other phthalates were detected less frequently. In some instances phthalates were detected in the field blanks but because they were also found in method blanks, the phthalates in the field blanks were qualified as non-detect with elevated detection limits (see Section 5.0). The only other SVOC detected was naphthalene in the field blank collected at Lander II Regulator Station.

PCBs were detected in all field blanks. Higher concentrations of PCBs were found in the field blanks collected from Hanford #2 and Lander II regulator station when compared with other field blank results. Tubing used to collect samples at these two locations had to be decontaminated in place whereas tubing at all other locations could be decontaminated at the laboratory. Even with differences in field blanks for PCBs, no significant bias is expected for PCB CSO samples because PCBs concentrations in CSO samples were always greater than five times the concentration found in field blanks.

With the exception of cadmium, no significant bias is expected in the CSO samples based on field blank metals results. The metal concentrations detected in the CSO samples were greater than five times those detected in the field blanks. Cadmium was detected in all three Duwamish Siphon Forebay CSO samples (see Appendix C) at concentrations less than five times the concentration detected in the field blank collected at this location. There is possible high bias to these sample results based on field blank results.

There is a possible high bias in the Duwamish Siphon Forebay CSO samples for benzyl butyl phthalate and diethyl phthalate results, which were typically detected in CSO samples at concentrations less than five or ten times the concentrations detected in the field blanks. For CSO samples collected at the Michigan St. Regulator there is a possible high bias for the three phthalates detected in the field blank because concentrations were often within five times that found in the field blank. This same potential high bias exists for diethyl phthalate in Hanford #2 CSO samples. Finally, for CSO samples collected at Lander II Regulator Station, there is possible high bias for phthalate compounds detected as well as for naphthalene in all but one sample, which had concentrations greater than five times the field blank.

5.0 DATA VALIDATION

This section provides an overview of the data validation findings. Data validation was performed for all datasets. Data validation for analyses performed by King County Environmental Laboratory included a review of holding times, method blanks, spike blanks, matrix spike/matrix spike duplicates, standard reference materials or laboratory control samples, laboratory replicates and surrogates. QA Level 1 review of the chemistry data was conducted in accordance with the QA/QC requirements and technical specifications of the methods and the national functional guidance for organic and inorganic data review (EPA 2001, 2004). Full data validation summary memorandum and associated quality assurance/quality control results are presented in Appendix E.

Data validation for PCB congener data followed the approach outlined in US EPA CLP National Functional Guidelines for Low Concentration Organic Data Review (EPA 2001) but using the criteria and acceptance limits defined in Method 1668A, Revision A (EPA 1999) and the CSO SAP (King County 2007). The data validation includes instrument related QC results such as calibration checks and QA Level 1 review where applicable to the method. Full data validation summary memos are presented in Appendix E.

Data validation for dioxin/furan congeners followed the approach outlined in US EPA Region 10 Standard Operation Procedures (SOP) for the validation of polychlorinated dibenzodioxin and polychlorinated dibenzofuran data (EPA 1996). The data validation includes instrument related QC results such as calibration checks and QA Level 1 review where applicable to the method. Full data validation summary memos are presented in Appendix E.

The majority of the data did not require qualification. Some analytes were qualified with a J, indicating an estimated value. Data validation resulted in rejecting the following because of spike blank recoveries: aniline in one sample, benzoic acid in three samples, bis(2-ethylhexyl)phthalate in one sample, hexachlorocyclopentadiene in four samples, pyridine in twelve samples. Data validation resulted in rejecting the following because of matrix spike/matrix spike duplicates recoveries: 1,3-dichlorobenzene in one sample, 3,3-dichlorobenzene in three samples, 4-chloroaniline in four samples, 4-nitroaniline in five samples, 4-nitroaniline in one sample, and 3-methylphenol in one sample. Finally, results for all chlorinated pesticide compounds in sample L49416-2 were rejected due to 0% recoveries of both surrogate compounds. Based on the information reviewed, all data except those that were rejected are of acceptable quality. Issues that resulted in the qualification of data are summarized below.

- As a general data reporting format, sample results that are reported as “less than the method detection limit” (<MDL) were assigned a “U” flag in all cases.
- The ammonia and nitrate + nitrite nitrogen results for sample L45811-1, L47992-1 and L47992-2 were qualified with a “J” flag, with an unknown bias, due to exceedence of the filtration holding time.
- The dissolved organic carbon result for sample L45811-1 was qualified with a “J” flag, with an unknown bias, due to exceedence of the filtration holding time.

- A data anomaly form was completed for sample L43913-2, indicating that chloride and ammonia levels measured in the sample could interfere with the chemical oxygen demand analysis, resulting in an estimated chemical oxygen demand sample result. Chemical oxygen demand analysis was performed after expiration of the prescribed 28-day holding time on samples L49003-1, and L49003-2. The chemical oxygen demand result for these samples were qualified with a "J" flag, with an unknown bias.
- Those dissolved mercury sample results that are reported as "less than the reporting detection limit" (<RDL) were assigned a "J" flag and considered estimated.
- Dissolved mercury data for samples L47992-1, L47992-2, L48009-1 through L48009-5, and L48009-7 were qualified with a "UJ" flag, with an unknown bias because of being filtered outside of the 15-minute prescribed holding time for filtration. In addition dissolved mercury data for sample L49199-5 were qualified with a "UJ" flag, with an unknown bias because no matrix-specific accuracy or precision information for this work group was available.
- Those total mercury sample results that are reported as "less than the reporting detection limit" (<RDL) were assigned a "J" flag and considered estimated.
- Those dissolved metals sample results that are reported as "less than the reporting detection limit" (<RDL) were assigned a "J" flag and considered estimated. The arsenic result for sample L46918-3 should be qualified with a "J" flag (high bias) due to the matrix spike recovery that exceeded the upper control limit. Due to the lack of any matrix specific accuracy or precision data[9], results for all dissolved metals in samples L47992-1 through L47992-3, L48009-1 through L48009-5, L48009-7, L49199-5, L49416-2, L49487-1, L49556-3, L49832-1, and L49844-1 were qualified with a "J" flag, with an unknown bias.
- Those total metals sample results that are reported as "less than the reporting detection limit" (<RDL) were assigned a "J" flag and considered estimated. Due to the lack of any matrix specific accuracy or precision data (due to insufficient sample volume), results for all total metals in samples L47992-1, L47992-2, L48009-1 through L48009-5, L48009-7, L49199-5, L49832-1, and L49844-1 were qualified with a "J" flag, with an unknown bias.
- 4,4'-DDT and Gamma-BHC (Lindane) results in sample L47190-2 were qualified with a "UJ" flag (low bias) due to spike blank recoveries below the lower QC limit. 4,4'-DDT and Gamma-BHC (Lindane) results in sample L49832-1 were qualified with a "J" flag (unknown bias) due to poor matrix spike/matrix spike duplicate precision. Results for all chlorinated pesticide compounds in sample L49556-3 were qualified with a "J" flag due to lack of a matrix-specific matrix spike and matrix spike duplicate analysis. Finally, results for all chlorinated pesticide compounds in sample L49416-2 were qualified with a "R" flag (rejected) due to 0% recoveries of both surrogate compounds.
- Semivolatile Organic Compound data qualification issues based on QC sample results, and required flagging, are summarized in Attachment D to both validation memoranda

[9] There was insufficient sample volume to perform these QC analyses.

included in Appendix E. The types of QC results that resulted in validation flags were method blank contamination (mostly affected phthalate compounds), spike blank recoveries out of control limits or matrix spike/matrix spike duplicate recoveries outside of control limits. In addition, as noted above, six compounds had some of their results rejected due to extremely low spike recovery results or and six compounds has some of their results rejected due to matrix spike and/or matrix spike duplicate recoveries of 0%. All semivolatile organic compound results for samples L47834-1, L47834-2, L47834-3, L47834-4 L49199-5, L49487-1, and L49556-3 were qualified with either a "J" flag (detected values) or a "UJ" flag (non-detected results) and considered estimated, due to the lack of QC information regarding method precision.

- Select PCB congeners in some of the CSO samples were U flagged because sample concentrations were within five times the method blank concentrations (see Appendix E). In addition, some congeners that were K flagged by the laboratory were U flagged following data validation. The K flag was due to quantification criteria not being met. Based on either lab duplicate or field duplicate results, a few congeners were J flagged because of high relative percent differences between duplicate results.
- Dioxin/furans in samples L47992-2 and L48009-2 were all J flagged for detected compounds and UJ flagged for all non-detected compounds due to holding times not being met. Select dioxin/furan congeners in some of the CSO samples were U flagged because sample concentrations were within five times the method blank concentrations (see Appendix E). In addition, some congeners that were K flagged by the laboratory were U flagged following data validation. The K flag was due to quantification criteria not being met. Finally, select congeners in samples L49003-1 and L49199-5 were J flagged for detected compounds and UJ flagged for all non-detected compounds due to internal standard recoveries outside of QC limits.

6.0 REFERENCES

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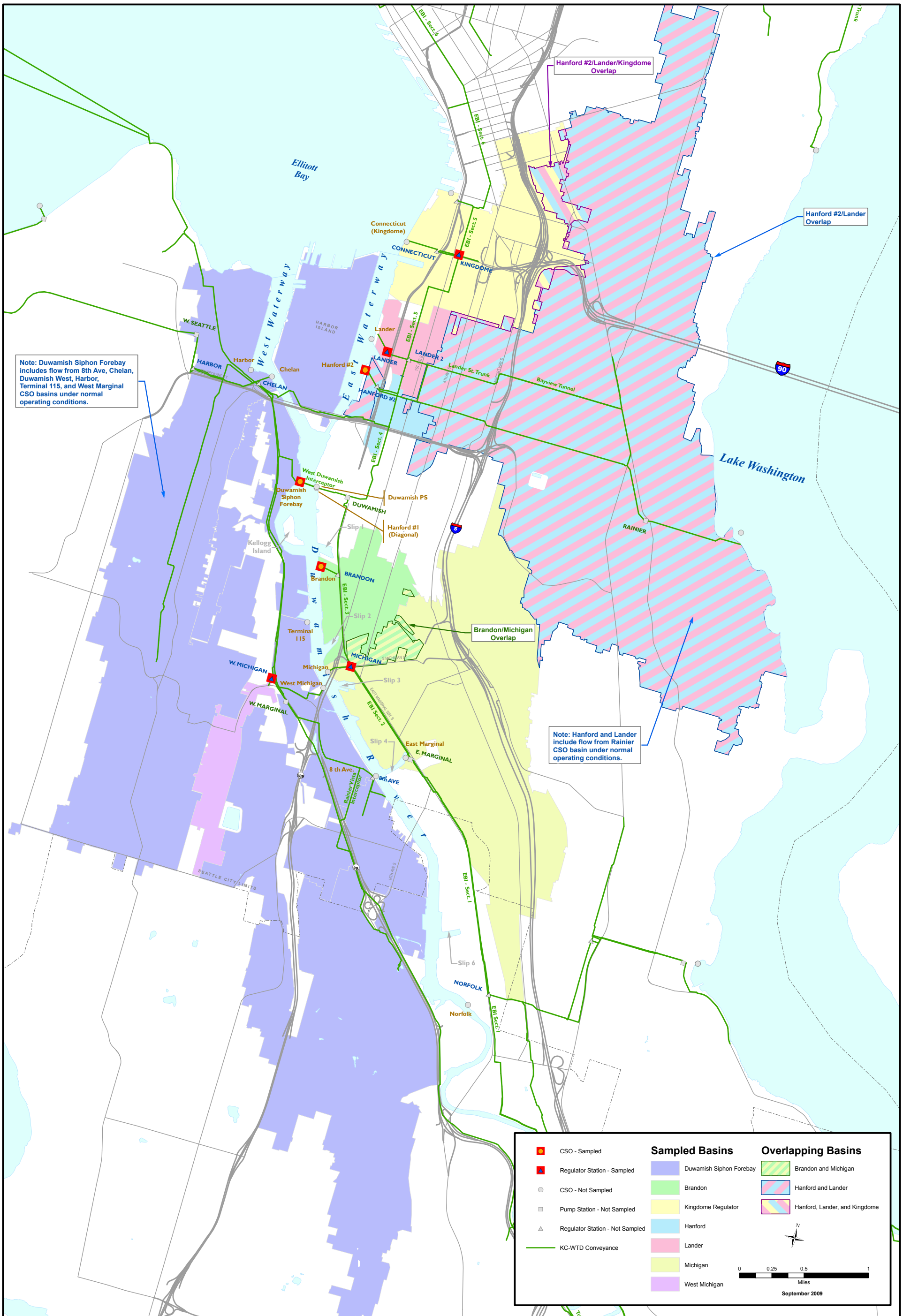

King County
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Wastewater Treatment Division

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Shaun O'Neil 20090109

Figure 1

Lower Duwamish River Sampled King County Basins, Facilities, and Outfalls

CSO Data Report

APPENDICES

APPENDIX A:
CHAIN-OF-CUSTODY FORMS

THIS APPENDIX IS AVAILABLE IN ELECTRONIC FORMAT (PDF)

APPENDIX B:
SAMPLE META DATA

THIS APPENDIX IS AVAILABLE IN ELECTRONIC FORMAT (PDF)

APPENDIX C:
KING COUNTY ENVIRONMENTAL LABORATORY SAMPLE DATA RESULTS

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APPENDIX D:
AXYS ANALYTICAL PCB AND DIOXIN/FURAN CONGENER SAMPLE DATA RESULTS

THIS APPENDIX IS AVAILABLE IN ELECTRONIC FORMAT (PDF)

APPENDIX E:
VALIDATION SUMMARY MEMOS

THIS APPENDIX IS AVAILABLE IN ELECTRONIC FORMAT (PDF)