# Lower Duwamish Waterway Source Control: Green River Watershed Suspended Solids Data Report

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Department of Natural Resources and Parks Water and Land Resources Division Science and Technical Support Section King Street Center, KSC-NR-0600 201 South Jackson Street, Suite 600 Seattle, WA 98104 206-477-4800 TTY Relay: 711

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# Lower Duwamish Waterway Source Control: Green River Watershed Suspended Solids Data Report

### **Prepared for:**

King County Wastewater Treatment Division Department of Natural Resources and Parks

### Submitted by:

Carly Greyell and Debra Williston King County Water and Land Resources Division Department of Natural Resources and Parks



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i

## **Table of Contents**

Execut	ive Summary	xi
1.0.	Introduction	1-1
1.1	Study Background	1-2
1.2	Study Area	1-3
2.0.	Field Sampling Methods	2-1
2.1	Sample Locations	2-1
2.2	Sampling Collection and Processing	2-2
2.	2.1 Suspended Solids Characterization – Sediment Traps	2-2
2.	2.2 Suspended Solids Characterization – Filtered Solids	2-4
2.3	Sampling Events	2-5
2.	3.1 Precipitation and Flow	2-8
2.4	Field Sampling Deviations from the SAP	2-11
3.0.	Laboratory Methods	3-1
3.1	Conventional Parameters	3-1
3.2	Metals and Mercury	3-3
3.3	PAHs and other Semi-Volatile Compounds	3-3
3.4	Pesticides	3-4
3.5	PCBs	3-4
3.6	Dioxin/Furan Congeners	3-4
3.7	Analytical Deviations from the SAP	3-5
4.0.	Data Analysis	4-1
4.1	Summation for PAHs, PCBs and Dioxins/Furans	4-1
4.2	Comparison to LDW Cleanup Goals	4-2
4.3	Statistical Analysis	4-3
5.0.	Sediment Trap Results	5-1
5.1	Particle Size Distribution	5-1
5.2	Total Organic Carbon	5-3
5.3	Metals	5-4
5.4	Polycyclic Aromatic Hydrocarbons	5-7
5.5	Other Semi-Volatile Compounds	

5.6	PCBs	5-14
5.7	Dioxin/Furan Congeners	5-16
5.8	Chemistry Data Validation	5-18
5	8.1 KCEL Data	5-18
5	8.2 PCBs and Dioxin/Furans	5-19
5.9	Equipment Blank	5-20
6.0.	Sediment Trap Discussion	6-1
6.1	Temporal Observations	6-1
6.2	Spatial Comparisons	6-2
7.0.	Filtered Solids Results	7-1
7.1	Particle Size Distribution	7-2
7.2	Metals	7-7
7.3	Mercury	7-10
7.4	Polycyclic Aromatic Hydrocarbons	7-10
7.5	PCBs	7-15
7.6	Dioxin/Furan Congeners	7-20
7.7	Chemistry Data Validation	7-22
7.	7.1 KCEL Data	7-22
7	7.2 PCBs and Dioxins/Furans	7-23
7.8	Equipment Blank	7-25
8.0.	Filtered Solids Discussion	8-1
8.1	Baseflow versus Storm Event Concentrations	
8.2	Spatial Comparisons	8-2
8.3	Relationships between Chemical Concentrations and Average Flow	8-8
9.0.	Method Comparison Section	9-1
9.1	Sediment Trap Method Comparison: Baffle vs. Jar	9-1
9.2	Baffle Sediment Trap vs. Filtered Solids Methods	9-5
10.0.	Conclusions	
11.0.	References	11-1

## Figures

Figure 1-1.	Sampling Locations and Land Use in the Green/Duwamish Watershed	1-5
Figure 5-1	PSD in Baffle Sediment Traps by Sample Period and Site	5-3
Figure 5-2.	Percent TOC in Baffle Sediment Trap Samples by Site and Period	5-4
Figure 5-3.	Arsenic Concentrations in Baffle Sediment Trap Samples by Site and Period, Compared to LDW Cleanup Goals	5-7
Figure 5-4.	Phenanthrene Concentrations in Baffle Sediment Trap Samples by Site and Period	. 5-10
Figure 5-5.	Total HPAH Concentrations in Baffle Sediment Trap Samples by Site and Period	. 5-11
Figure 5-6.	Total cPAH TEQ in Baffle Sediment Trap Samples by Site and Period, Compared to the LDW Human Health Cleanup Goals	. 5-12
Figure 5-7.	Total PCB Concentrations in Baffle Sediment Trap Samples by Site and Period, Compared to the LDW Human Health Cleanup Goal	. 5-15
Figure 5-8.	PCB Homolog Patterns in Baffle Sediment Trap Samples by Site and Period	. 5-16
Figure 5-9.	Total Dioxin TEQs in Baffle Sediment Trap Samples by Site and Period, Compared to the LDW Human Health Cleanup Goals	. 5-17
Figure 6-1.	Green River Main Stem Baffle Trap Sediment Sample Results by Period: (a) Percent Fines, (b) TOC, (c) Arsenic, (d) Fines-normalized Arsenic, (e) Total PCBs, (f) OC-normalized PCBs, (g) Total Dioxin TEQs, (h) OC- normalized Dioxin TEQs	6-4
Figure 6-2.	Tributary Baffle Trap Sediment Sample Results by Period: (a) Percent Fines, (b) TOC, (c) Arsenic, (d) Fines-normalized Arsenic, (e) Total PCBs, (f) OC-normalized PCBs, (g) Total Dioxin TEQs, (h) OC-normalized Dioxin TEQs	6-5
Figure 7-1.	Particle Size Distribution in Samples by Location and Sampling Date	7-5
Figure 7-2.	Mean Particle Distribution in Samples at Each Location during Storm Events	7-6
Figure 7-3.	Arsenic Concentrations in Filtered Solis Samples by Location Compared to the LDW Human Health and Benthic Cleanup Goals	7-9
Figure 7-4.	Total LPAH Concentrations in Filtered Solids Samples by Location	. 7-12
Figure 7-5.	Total HPAH Concentrations in Filtered Solids Samples by Location	.7-14
Figure 7-6.	Total cPAH TEQs in Filtered Solids Samples by Location Compared to LDW Cleanup Goals	. 7-15

Figure 7-7.	Total PCB Concentrations in Filtered Solids Samples by Location Compared to the LDW Human Health and Benthic Cleanup Goals	7-17
Figure 7-8.	PCB Homolog Pattern for Green River Main Stem Filtered Solids Samples	7-18
Figure 7-9.	PCB Homolog Patterns for Tributary Filtered Solids Samples	7-19
Figure 7-10	. Total Dioxin TEQs in Filtered Solids Samples by Location Compared to LDW Cleanup Goals	7-21
Figure 8-1.	Statistical Comparison of Percent Fines in the Green River Main Stem and Tributaries during Storm Events	8-3
Figure 8-2.	Statistical Comparison of Arsenic in the Green River Main Stem and Tributaries during Storm Events	8-4
Figure 8-3.	Statistical Comparison of Total LPAHs in the Green River Main Stem and Tributaries during Storm Events	8-4
Figure 8-4.	Statistical Comparison of Phenanthrene in the Green River Main Stem and Tributaries during Storm Events	8-5
Figure 8-5.	Statistical Comparison of Total HPAHs in the Green River Main Stem and Tributaries during Storm Events	8-5
Figure 8-6.	Statistical Comparison of Total cPAHs in the Green River Main Stem and Tributaries during Storm Events	8-6
Figure 8-7.	Statistical Comparison of Benzo(b,j,k)fluoranthene in the Green River Main Stem and Tributaries during Storm Events	8-6
Figure 8-8.	Statistical Comparison of Fluoranthene in the Green River Main Stem and Tributaries during Storm Events	8-7
Figure 8-9.	Statistical Comparison of Total PCBs in the Green River Main Stem and Tributaries during Storm Events	8-7
Figure 8-10	Statistical Comparison of Total Dioxin TEQs in the Green River Main stem and Tributaries during Storm Events	8-8
Figure 8-11	.Relationship between Average Flow and Total PCB Concentrations in Green River–Foster Links Storm Event Samples	8-10
Figure 9-1.	Comparison of PSD in Baffle and Jar Sediment Traps by Sample Period	9-2
Figure 9-2.	Relative Percent Difference between Chemical Concentrations in Paired Jar-Style and Baffle-Style Sediment Traps for each Sampling Period	9-4

## Tables

Table 1-1.	Drainage area for each Green River and tributary basin sampling location.	1-3
Table 2-1.	Green River and tributary sampling locations and locator names	2-1
Table 2-2.	Sediment trap sample identifications by location, collection period and sample type	2-6
Table 2-3.	Filtered Solids sample identifications by location, collection date, and flow type	2-7
Table 2-4.	Precipitation and flow gages associated used for each sampling location	2-8
Table 2-5.	Rainfall and flow data for each sediment trap sampling event	2-8
Table 2-6.	Rainfall and flow data for each filtered solids sampling event	10
Table 3-1.	Krumbein phi sizes utilized in the ASTM PSD method versus the combined sediment concentration (PSD-SC) and laser diffraction (PSD-LD) methods	3-2
Table 3-2.	Polycyclic aromatic hydrocarbon compounds and detection limit goals by SIM ( $\mu$ g/kg ww)	3-3
Table 4-1.	Carcinogenic PAH compounds and corresponding benzo(a)pyrene potency equivalency factor values	4-1
Table 4-2.	Dioxin and furan compounds and corresponding 2,3,7,8-TCDD toxicity equivalent factors applied in calculation of dioxin TEQs	<b>1-2</b>
Table 5-1.	Number of baffle trap samples analyzed by parameter type at each sample location	5-1
Table 5-2.	Summary of baffle trap PSD results by site and sampling period (% mass)	5-2
Table 5-3.	Summary of baffle trap TOC results by site and sampling period (% dw)	5-3
Table 5-4.	Summary of baffle trap metals by site and sampling period (mg/kg dw)	5-4
Table 5-5.	Frequency of detection for LPAHs and HPAHs in baffle sediment trap samples by site	5-7
Table 5-6.	Summary of phenanthrene and anthracene in baffle traps by site and sampling period ( $\mu$ g/kg dw)5	5-8
Table 5-7.	Summary of HPAHs in baffle traps by site and sampling period (µg/kg dw)	5-9
Table 5-8.	Summary of other baffle trap SVOCs ranked based on frequency of detection ( $\mu$ g/kg dw)5-	·13
Table 5-9.	Summary of total PCB results in baffle traps by site and sampling period ( $\mu$ g/kg dw)	-14

Table 5-10.	Summary of total dioxin/furans in baffle traps by site and sampling period ( $\mu$ g/kg dw).	5-16
Table 5-11.	Summary of total dioxin TEQs in baffle traps by site and sampling period (ng TEQ/kg dw).	5-17
Table 7-1.	Number of samples analyzed by parameter and flow type at each location.	7-1
Table 7-2.	Summary of filter solids PSD results by location and flow condition (% by volume)	7-2
Table 7-3.	Filtered solids metals results summarized by site and flow condition (mg/kg dw).	7-7
Table 7-4.	Filtered solids mercury results summarized by site and flow condition (mg/kg dw).	7-10
Table 7-5.	Frequency of detection for individual LPAHs by site during storm events.	7-10
Table 7-6.	Filtered solids total LPAH results summarized by site and flow condition ( $\mu$ g/kg dw).	7-11
Table 7-7.	Frequency of detection for individual HPAHs by site during storm events.	7-13
Table 7-8.	Total HPAH filtered solids results summarized by site and flow condition ( $\mu$ g/kg dw).	7-13
Table 7-9.	Total PCB filtered solids results summarized by site and flow condition $(\mu g/kg  dw)$	7-16
Table 7-10.	Total dioxin/furan filtered solids results summarized by site and flow condition ( $\mu$ g/kg dw).	7-20
Table 7-11.	Total dioxin TEQs filtered solids results summarized by site and flow condition (ng TEQ/kg dw).	7-21
Table 9-1.	Relative percent differences between analyte concentrations in the baffle and jar style sediment traps	9-2
Table 10-1.	Summary of sediment trap and filtered solids results.	10-2
Table 10-2.	Number of samples above site-wide LDW human health cleanup goals for baffle sediment trap and filtered solids samples	10-4

## Appendices

Appendix A: Chain of Custody Appendix B: Filtration Efficiency Evaluation Appendix C: Sampling Equipment Descriptions Appendix D: Analytical Data Results Appendix E: Relationships between Parameters Appendix F: Spatial Depictions of Additional Metals Appendix G: Data Validation Appendix H: Comparison of Baffle Trap and Filtered Solids Methods

μm	microns
dw	dry weight
kg	kilograms
mg	milligram
ng	nanogram
ASTM	American Standard Test Method
AXYS	AXYS Analytical Services, Ltd
CFS	cubic feet per second
cPAHs	carcinogenic polycyclic aromatic hydrocarbons
EPA	Environmental Protection Agency
FOD	frequency of detection
GC/ECD	Gas Chromatography – Electron Capture Detector
HRGC/HRMS	high resolution capillary column gas chromatography/high resolution mass spectrometry
ICP-MS	Inductively Coupled Plasma–Mass Spectrometry
KCEL	King County Environmental Laboratory
LDW	Lower Duwamish Waterway
LIMS	KCEL Information Management System
LMCLs	lowest method calibration limits
MDL	method detection limit

## Acronyms

polycyclic aromatic hydrocarbons
polychlorinated biphenyls
particle size distribution
particle size distribution- laser diffraction
particle size distribution-sediment concentration
polyvinyl chloride
quality control
reporting detection limit
relative percent difference
remedial investigation
sampling and analysis plan
specific detection limit
selected ion monitoring
semi-volatile organic compounds
toxicity equivalent
total organic carbon
total suspended solids
United States Geological Survey
Water and Land Resources Division

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# EXECUTIVE SUMMARY

King County has conducted several studies in the Green/Duwamish River Watershed that characterize the human health contaminants of concern identified for the Lower Duwamish Waterway (LDW) Superfund site. These studies have evaluated chemical concentrations in water and sediment upstream of the LDW and atmospheric deposition within the Green/Duwamish River Watershed; all of which can contribute contaminants to the LDW. This study presents an assessment of chemical concentrations associated with suspended solids in the Green River Watershed and provides context to better understand the potential for LDW contaminants of concern to be transported from the Green River to the LDW. This study focused on polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), dioxin/furans and arsenic. While not intended to directly quantify contaminant loading from the Green River to the LDW, study results will be useful for future loadings assessments. The results can also be used to help guide source control efforts; for example, identification of subbasins with elevated contaminant concentrations.

This study included collection and analysis of suspended solids samples from four major tributaries to the Green River, as well as at two locations in the Green River (up and down stream of the tributaries). Two sampling methods were used to characterize chemical concentrations in suspended solids; sediment traps and suspended solids collected on filters (referred to as filtered solids). The study was designed to address the following questions:

- **1. Sediment Traps and Filtered Solids Samples** What are the general chemical characteristics of suspended solids collected over the study period in four major tributaries to the Green River and in the main stem Green River at an upper and lower boundary location?
- 2. Filtered Solids Samples How do concentrations of PCBs, PAHs, dioxins/furans and arsenic associated with suspended solids samples within the Green River Watershed differ between locations during dry season/baseflow and wet season/storm conditions?
- **3. Sediment Traps and Filtered Solids Samples** What are the general spatial differences of PCBs, PAHs, dioxins/furans and arsenic in the major tributaries and the Green River?

The sediment traps were deployed five times for approximately three months each between 2012 and 2015. The filtered solids samples were collected between 2013 and 2015 during baseflow or storm conditions. At most sites, one baseflow and five storm samples were collected over an approximately 24 hour period. The following presents the general findings of this study.

#### **Results and Discussion**

The table below presents a general summary of the LDW human health contaminants of concern for both sediment traps and filtered solids. When sediment trap and filtered solids results were compared to the lowest site-wide human health based cleanup goals<sup>1</sup> for the LDW Superfund site, the following percent of samples exceeded these goals: 75% for arsenic, 13% for carcinogenic PAHs (cPAHs), 69% for total PCBs and 77% for dioxin TEQs.

Parameter	Location	Sedimo	ent Traps	Filtered Solids	
i di dineter	Looution	Jar-Style <sup>a</sup>	Baffle-Style <sup>b</sup>	Baseflow <sup>c</sup>	Storm d
Arsenic	Green River – FG		9.12	15.0	11.1
(mg/kg dw)	Newaukum Creek		3.37	7.28	7.59
	Soos Creek		5.32	9.64	11.0
	Mill Creek	9.93	11.3	42.7	21.8
	Black River/SC		49.4	47.5	35.5
	Green River – FL	11.1	8.86	39.9	14.2
Total cPAHs	Green River – FG		13 J	3.91 J	11.1 J
(µg TEQ/kg dw)	Newaukum Creek		10 U	28.3 J	54.4 J
	Soos Creek		19 J	82.0 J	70.4 J
	Mill Creek	69.3 J	57.0 J	94.3 J	157 J
	Black River/SC		672 J	439 J	916 J
	Green River – FL	54.0 J	45.4 J	35.8 J	160 J
Total PCBs	Green River – FG		0.363 J	1.48 J	2.93 J
(µg/kg dw)	Newaukum Creek		0.209 J	5.78 J	3.60 J
	Soos Creek		3.00 J	6.83 J	5.53 J
	Mill Creek	5.2 J	7.50 J	10.2 J	12.5 J
	Black River/SC		44.4 J	38.1 J	116 J
	Green River – FL	12.7 J	5.27 J	7.75 J	29.9 J
Dioxin TEQ	Green River – FG		0.837 J	1.37 J	2.02 J
(ng TEQ/kg dw)	Newaukum Creek		0.945 J	9.97 J	6.92 J
	Soos Creek		2.06 J	5.31 J	6.08 J
	Mill Creek	4.59 J	5.85 J	11.7 J	17.0 J
	Black River/SC		16.6 J	10.2 J	21.9 J
	Green River – FL	3.04 J	1.92 J	3.48 J	7.11 J

Summary	/ of	Sediment	Trap	and	Filtered	Solids	Results
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<sup>a</sup> Jar-style sediment traps deployed at Mill Creek (Period 1) and Green River–Foster Links (Periods 2-5). <sup>b</sup> Mean of up to 5 sampling periods depending on parameter

<sup>c</sup> Mean of 2 samples in Black River/Springbrook Creek basin and 3 samples at Green River-Foster Links; one sample at the other sites.

<sup>d</sup> Mean of up to 7 samples depending on parameter and location..

See Tables 5.1 and 7.1 for sample numbers.

FG – Flaming Geyser; FL – Foster Links; SC – Springbrook Creek

- sample not collected; J - estimated value; U - non-detect; dw - dry weight; TEQ - toxicity equivalents

<sup>&</sup>lt;sup>1</sup> With the exception of cPAHs, these cleanup goals are based on natural background levels for Puget Sound.

Filtered solids results were compared across baseflow and storm event conditions. The highest arsenic concentrations were almost always observed during baseflow conditions. At most sites, average concentrations of PCBs, PAHs and dioxins were higher during storm conditions, particularly at the most downstream locations (Mill Creek, Black River/Springbrook Creek, and Green River–Foster Links). These results suggest stormwater runoff contributes contaminants through transport of suspended solids, especially at the more urbanized downstream sites.

Both sediment trap and filtered solids results indicate some of the highest chemical concentrations were detected at the more highly developed downstream sites: Mill Creek, the Black River/Springbrook Creek basin, and Green River–Foster Links. Concentrations were generally highest in the Black River/Springbrook Creek basin.

Metals and organic chemicals are often preferentially associated with finer grain sediment particles (fines) and/or the organic carbon/matter. As such, these factors can influence the chemical concentrations in suspended solids. The highest chemical concentrations were almost always observed in sediment trap samples during the sampling period with highest percent fines and/or total organic carbon (TOC). Although the percent fines in filtered solid samples were relatively similar in samples from the same site<sup>2</sup>, higher chemical concentrations were generally observed in tributary samples containing higher levels of fine particles. This pattern was less consistent across the two main stem sites.

Flow conditions can also influence both size of suspended particles collected and the chemical concentrations observed. This is particularly important to consider for the main stem Green River sites where flow is highly influenced by Howard Hanson Dam operations. Results at Green River–Foster Links suggest chemical concentrations in filtered solids storm samples collected during significant dam releases (more flow from the less developed area upstream of the dam) were lower than levels in storm samples collected during lower flows, but under high rainfall conditions (more flow from local runoff, with more developed land use). A recent study by USGS found a similar trend at this site.

### **Comparison of Sampling Methods**

Two sediment trap styles were used: baffle and jar. Preliminary testing indicated the bafflestyle sediment traps would collect a greater volume of material; therefore, these were used at sites during each sampling period. Jar-style sediment traps, which are the more traditional method, were deployed at one site per sample period for comparison purposes. Chemical concentrations in jar-style trap samples were generally higher than levels detected in the paired baffle-style trap samples, but for most parameters, the differences were relatively small (i.e., within the allowable limits for variability in laboratory replicates). The greatest differences were observed for PCBs. The jar-style trap tended to collect slightly finer grained particles with higher TOC content than the baffle-style trap. As previously discussed, TOC content could have influenced the differences observed in chemical concentrations.

<sup>&</sup>lt;sup>2</sup> TOC was not analyzed in filtered solids samples due to false positives from the filter material; thus, chemical relationships to TOC could not be explored for these samples.

While the filtered solids and baffle-style sediment trap methods are not meant to be directly comparable, general observations were made. The results suggest the filtered solids method may collect samples with higher fines content and chemical concentrations than the baffle sediment traps. Percent fines, as previously discussed, may have influenced the observed chemical concentrations.

#### Conclusions

Chemical concentrations were higher in more urbanized areas. The highest chemical concentrations were detected in both traps and filtered solids samples in the Black River/Springbrook Creek basin. In filtered solids samples, arsenic concentrations and percent fines were higher during baseflow conditions, while cPAHs, total PCBs and dioxin/furans were often higher during storm event conditions.

#### Next Steps

These data will be used by Ecology and EPA for the Green/Duwamish Pollutant Loading Assessment. The Pollutant Loading Assessment is intended to identify upstream pollution sources as well as strategies to reduce those sources to support EPA's Lower Duwamish inwaterway cleanup. Data from this study and other recent studies can be used to estimate particulate contaminant inputs to the LDW from upstream sources.

The overall goal of this study was to better understand chemical characteristics of suspended solids upstream of the LDW. However, the suspended solids data do not necessarily represent what settles in the LDW. The sediment transport model for the LDW estimated only 50% of the incoming material settles in the LDW and that percentage varies by particle size class. In addition, data variability, particularly as it relates to rainfall and flow patterns needs to be considered when estimating chemical loading and deposition from Green River to the LDW. Therefore, to accurately determine the chemical composition of what settles in the LDW, additional analyses are necessary.

Finally, data from this and other recent King County studies in the Green River Watershed provides a better understanding of the location and concentration of various contaminants, along with the potential pathways by which they are transported to the LDW.

# **1.0. INTRODUCTION**

This study presents an assessment of suspended solids quality in the Green River Watershed to characterize chemical concentrations associated with suspended solids in the Green River and its major tributaries. An additional study goal is to understand the relative differences in suspended solids chemical concentrations between these areas. This study also provides additional context to understand the potential for polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), dioxin/furans and arsenic to be transported from the Green River to the Lower Duwamish Waterway (LDW), where they are human health contaminants of concern. While not intended to directly quantify contaminant loading from the Green River to the LDW, results of this study may be used to focus more detailed loadings assessments and/or to assist in source control studies to identify subbasins/areas in the Green River Watershed that contribute significant levels of contaminants to the Green River.

This study includes collection and analysis of suspended solids samples from four major tributaries to the Green River, as well as at two main stem Green River locations (up and down stream of the tributaries). Two different sampling methods were used to characterize chemical concentrations in suspended solids; sediment traps and suspended solids collected on filters (referred to as filtered solids in this report). The study was designed to address the following questions:

- **1.** Sediment Traps and Filtered Solids Samples What are the general chemical characteristics of suspended solids collected over the study period in four major tributaries to the Green River and in the main stem Green River at an upper and lower boundary location?
- 2. Filtered Solids Samples How do concentrations of PCBs, PAHs, dioxins/furans and arsenic associated with suspended solids samples within the Green River Watershed differ between locations during dry season/baseflow and wet season/storm conditions?
- **3. Sediment Traps and Filtered Solids Samples** What are the general spatial differences of PCBs, PAHs, dioxins/furans and arsenic in the major tributaries and the Green River?

This report is organized as follows: study background and geographic study area (Section 1.0); sample collection and processing methods (Section 2.0); laboratory analytical methods (Section 3.0); data analysis procedures (Section 4.0); sediment trap study results and discussion (Sections 5.0 and 6.0); filter solids study results and discussion (Sections 7.0 and 8.0); a comparison of sampling methods (Section 9.0); and conclusions (Section 10.0). Supporting appendices include chain of custody forms, laboratory data results, chemistry data validation reports, results for chemicals that are not human health contaminants of concern for the LDW, and an evaluation of the efficiency of the filtered solids filtration method in capturing solids of various particle sizes.

## 1.1 Study Background

King County is a member of the Source Control Work Group for the LDW Superfund site. Other members include Washington State Department of Ecology (lead agency), the Environmental Protection Agency (EPA), City of Seattle, and the Port of Seattle. The Source Control Work Group collaborates to understand potential sources of contaminants to the LDW Superfund site and works to control and reduce sources that can contaminate sediments and resident fish and shellfish in the waterway. King County wants to better understand potential sources and pathways of the contaminants of concern identified in the LDW Superfund site that may contribute chemical inputs to the LDW. As part of this effort, King County recently completed sediment and water quality studies in the Green River Watershed (King County 2014a; b; 2015a). The Green River is one pathway that contributes contaminants to the LDW. The County also recently measured chemical mass flux in atmospheric deposition within the Green/Duwamish River Watershed (King County 2008; 2011a; 2013a; b; 2015b). Air deposition is another pathway by which contaminants can enter the watershed, and thus, the LDW.

The LDW Remedial Investigation (RI) (Windward 2010) indicates that on an annual basis more than 99% of the new sediment deposited in the LDW originates upstream of the LDW in the Green/Duwamish River. As a result, future LDW surface sediment quality following sediment cleanup will be closely tied to the quality of incoming sediment from the Green/Duwamish River. Recent assessments have evaluated the current chemical concentrations in suspended solids in the Green River (Gries and Sloan 2009; Conn et al. 2015). The study presented here is intended to complement data from previous studies in the Green/Duwamish Watershed and is an important next step for King County.

The primary purpose of this sampling and analysis effort is to provide a better understanding of the current and relative concentrations of select contaminants in suspended solids from four tributaries to the Green River, as well as two main stem river locations. The data collected by this study, along with previous water and sediment data collection efforts, will serve to better characterize contaminant conditions upstream of the LDW. This study focuses on PCBs, PAHs, dioxins/furans and arsenic because the LDW RI identified these as human health contaminants of concern. In addition, the LDW Feasibility Study predicted the Puget Sound based natural background cleanup goals for PCBs, dioxins/furans and arsenic are not likely to be achieved following sediment cleanup due to ongoing urban and upstream sources. While this study does not estimate contaminate loading to the LDW, the data can be used to help characterize the contaminants being exported to the LDW. This information can be used to assist in development of future studies to evaluate contaminant loading to the LDW. The results of this study can also be used to inform future source control efforts in the watershed. These data, combined with data from other studies, will enhance the current understanding of the location and magnitude of various contaminant inputs, the contribution from different media and transport through the system, and their ultimate impact on the LDW.

## 1.2 Study Area

The Green/Duwamish Watershed includes approximately 484 square miles of varied terrain and land uses ranging from forested headwater areas at the crest of the Cascade Mountains to the industrial and port facilities of the LDW and East and West Waterways.<sup>3</sup> The study area encompasses the lower Green/Duwamish River and middle Green River in addition to the following major tributary basins: Newaukum, Soos and Mill creeks and the Black River/Springbrook Creek. The study area extends along the main stem Green River from Flaming Geyser State Park (River Mile 41)<sup>4</sup> to the Foster Links Golf Course (River Mile 10) <sup>5</sup> and includes the major tributaries entering the Green River between these locations. The size of the drainage area upstream of each Green River main stem sampling location and tributary basin is shown in Table 1-1.

	Site	Acreage	
Main Stom	Green River – Flaming Geyser	166,028ª	
Main Stem	Green River–Foster Links	294,339ª	
	Newaukum Creek	17,280	
Tributary	Soos Creek	42,347	
Basins	Mill Creek	10,150	
	Black River <sup>b</sup>	17,231	
<ul> <li><sup>a</sup> Includes all upstream basins except closed systems within the watershed that do not drain to the Green River (Coal and Deep creeks)</li> <li><sup>b</sup> Includes Springbrook Creek (16,752 acres drainage basin), which becomes the Black River</li> </ul>			

Table 1-1.	Drainage area	for each Green	<b>River and</b>	tributary basin	sampling location.
					J

The Green/Duwamish Watershed encompasses a wide variety of land uses<sup>6</sup> (Figure 1-1). Land use in the upper Green River basin, above the Howard Hanson Dam, consists of natural resource land: much of which is within a protected watershed that serves as a drinking water source. Land use in the middle Green River above Flaming Geyser State Park consists largely of natural resource/open space, in addition to some residential land use (Figure 1-1). Land use in the Newaukum and Soos Creek basins is dominated by

<sup>&</sup>lt;sup>3</sup> The Green River Watershed excludes the LDW and East and West Waterways and their associated drainage areas.

<sup>&</sup>lt;sup>4</sup> River mile 0 is at the southern end of Harbor Island; consistent with LDW river mile designations.

<sup>&</sup>lt;sup>5</sup> This area of the river is also referred to as the Duwamish River, which originates at the confluence of the Green and Black Rivers near Tukwila, WA and flows northwest for approximately 19 km (12 mi), splitting at the southern end of Harbor Island to form East and West Waterways, prior to discharging into Elliott Bay.. <sup>6</sup> Land use categories represent current use (i.e., not based on zoned uses) and designated based on King

County Assessor data (May 2013). Residential land was split into urban and rural based on the Urban Growth Area Line for 2013. Parcels with >50% cultivated land cover, based on 2007 Land Cover classification, were designated as agricultural land.

residential and natural resource/open space. However, the Soos Creek basin also includes some commercial and utilities land use, while the Newaukum basin includes agricultural land use. Of the tributary basins, land use in the Black River and Mill Creek basins is the most diverse. The Mill Creek Basin consists of mixed land use with approximately 51% residential and natural resources, 13% manufacturing/industrial, 8% commercial and 6% agricultural land. The Black River Basin contains the largest percentage of commercial and manufacturing/industrial land (33%). While land use in the area immediately adjacent to the Green River in the vicinity of the Foster Links Golf Course is dominated by residential land use, it also includes commercial and manufacturing/industrial uses (Figure 1-1).



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File Name: \\dnrp1\projects\wtd\projects\greenduwamish\projects\2013waterreport/LandUse10\_H2O\_v4.mxd Shaun O'Neil 20151009 \*Land use categories were designated based on King County Assessor data from May, 2013. Residential land was split into urban and rural based on the Urban Growth Area Line for 2013. Parcels with over 50% cultivated land cover, based on the 2007 Landsat Landcover classification, were designated as agricultural land.



Figure 1-1 Sampling Locations And Land Use In The Green/Duwamish Watershed

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## 2.0. FIELD SAMPLING METHODS

The following section provides an overview of the field sampling methods used in this study. The field procedures are described in greater detail in the project Sampling and Analysis Plan (SAP) (King County 2013c). A description of the sampling events and deviations from the SAP related to field sampling methods are also presented. Copies of completed chain of custody forms are included in Appendix A.

## 2.1 Sample Locations

Suspended solids samples were collected from seven locations in the Green River Watershed (see Table 2-1). Both filtered solids and sediment trap samples were collected at each location with the exception of the Black River Pump Station (see rationale below). Two sampling sites were located on the main stem Green River; an upstream location at Flaming Geyser State Park (upriver of the major tributaries being sampled), and a downstream location at Foster Links Golf Course in Tukwila (downstream of the tributaries) (Figure 1-1). Five sampling sites were located on four tributaries to the Green River: Newaukum, Soos and Mill creeks and the Black River (Figure 1-1). Samples from Newaukum and Soos creeks were collected near the mouth above their confluence with the Green River. Samples from Mill Creek were collected downstream of the West Valley Highway bridge. Two sampling locations were located in the Black River Basin: the Black River Pump Station and Springbrook Creek. Only filtered solids samples were collected from the Black River Pump Station because sediment traps could not be installed at this location. The pump station regulates discharge from the Black River at a dam located about 1,000 feet above its confluence with the Green River. The pump station regulates flow of water from the Black River drainage basin into the Green River and serves to block high flows from the Green River from flooding up into the Black River, Springbrook Creek, and the Earlington Industrial Park in Renton. Water is discharged at this location through a series of pumps and a seasonal fish passage channel. The filtered solids samples were collected from the fish passage channel during periods when it was operational (typically late summer through fall/early winter). Partway through the study, the Springbrook Creek location was added as an additional sampling site in the Black River Basin. Sediment trap samples from Springbrook Creek were collected from a publically accessible location, approximately 100 feet upstream from the center of the Oaksdale Ave SW Bridge, whereas filtered solids samples were collected approximately 220 feet upstream of the Oaksdale Ave SW Bridge; about half way between that bridge and the 7th Ave Bridge.

Locato	r <sup>a</sup>		Approx		
Sediment Trap	Filtered Solids	Locator Description	River Mile <sup>b</sup>	Northing <sup>c</sup>	Easting <sup>c</sup>
FG319_ST_BAF	FG319_FS	Green River – Flaming Geyser State Park Upstream of Newaukum Creek	41	104038	1341097

Table 2-1.	Green River and tributary sampling locations and locator names.
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Locator <sup>a</sup>			Approx		
Sediment Trap	Filtered Solids	Locator Description	River Mile <sup>b</sup>	Northing <sup>c</sup>	Easting <sup>c</sup>
FL319_ST_BAF FL319_ST_J	FL319_FS	Green River–Foster Links Golf Course Downstream of Confluence with Black River	10	177997	1288012
0322_ST_BAF	0322_FS	Mouth of Newaukum Creek	40	102390	1336841
A320_ST_BAF	A320_FS	Mouth of Soos Creek	33	116821	1309972
A315_ST_BAF A315_ST_J	A315_FS	Mouth of Mill Creek	23	137218	1289725
None	PS317_FS	Black River @ Black River Pump Station	10	176593	1291222
P317_ST_BAF	P317_FS	Springbrook Creek	N/A <sup>d</sup>	175755°	1292981 <sup>e</sup>

Note: "ST\_BAF" - baffle sediment trap, "ST\_J" - jar-style trap; and "FS" -filtered solids.

Bold Font shows location terminology used throughout report.

<sup>a</sup> Locator is a unique name given to a sampling location and used in the King County laboratory database.

<sup>b</sup> River Miles are based on south end of Harbor Island (lower boundary of LDW Superfund site) as river mile 0.0. Tributary river miles represent approximate point of discharge to Green River.

<sup>c</sup> State plane coordinates in North American Datum 1983 (NAD1983) Washington State Plane North (4601)

<sup>d</sup> Springbrook Creek becomes the Black River and does not directly discharge to the Green River; Springbrook Creek samples collected approximately 0.5 miles upstream Black River Pump Station.

<sup>e</sup> Northing and easting for Springbrook site are approximate due to slightly different sampling locations for collection of filtered solids and sediment trap samples (approximately 100 ft. apart).

## 2.2 Sampling Collection and Processing

All samples were collected by King County Environmental Laboratory's (KCEL) Field Sciences Unit following the procedures outlined in the SAP. The sample collection and processing for the two suspended solids sampling methods are summarized below. Water samples were also collected to measure total suspended solids (TSS) and particle size distribution (PSD) on a subset of filtered solids samples to evaluate filtration efficiency; the methods and results for this analysis are presented in Appendix B.

### 2.2.1 Suspended Solids Characterization – Sediment Traps

The sediment trap sampling strategy was designed to cumulatively collect suspended solids over a period of time to represent a variety of flow and storm event conditions. The targeted sampling period was approximately three months. The traps were designed to capture a representative sample of sediment particles that have been suspended in the water column over a variety of transport conditions. These sediment particles may be

resuspended from in the stream/river bed or be transported by stormwater/overland flow into the stream/river water column. Pilot testing of the two trap types (baffle and jar) in Mill Creek during the spring/summer of 2012 suggested that the baffle-style trap collected a greater mass of material than the simple, but more traditionally used jar trap. Therefore, the "baffle-style" trap was the primary sampling device used in this study; however, a "jarstyle" trap was also deployed at one location per collection period. Deployment of both trap types at one location allows for a more systematic comparison of the material captured by the two trap designs. Each style of sediment trap is described in more detail below.

Sediment traps deployed in tributary streams were placed as close as possible to the center of the stream, with the exception of Soos Creek where it was placed near the left bank in order to properly secure it. Traps deployed in the main stem Green River were placed closer to the river bank due to considerations of field crew safety and the difficulties associated with deploying and retrieving equipment in these locations.

Sediment trap samples were analyzed for PCBs, 17 dioxin/furan congeners, PAHs (along with other semi-volatile organic compounds [SVOCs]), arsenic (and other select metals), mercury, total solids, TOC and PSD. PCB analysis was as Aroclors<sup>®</sup>, per the SAP, but was modified to PCB congeners (all 209) after difficulties in detecting Aroclors in the samples. On occasion, sample mass was not sufficient for analysis of all the desired parameters.

### 2.2.1.1 Baffle Sediment Trap

Baffle-style trap housing unit is made of polyvinyl chloride (PVC) material and is 42 inches in length including reducers on both ends. Inside is a 6-inch diameter, 24 inch long trap made of aluminum. The inlet diameter is 1.5 inches, while the outlet diameter is 3 inches; the differing diameters are intended to slow water flow within the trap. The baffles within the trap are designed to help entrain solids (See Appendix C for photos). The baffle trap is deployed by attaching it to a set of cement blocks (approximately 8 inches in height) placed on the stream bed. When the trap is attached to the blocks, the base of the sampler inlet is approximately 11 inches above the stream bed.

Before removing the baffle trap from the river or creek, caps were screwed into both ends of the PVC housing unit tube. The tube was then released from the concrete anchors via quick releases and the PVC tube containing the baffle and sample was moved to a temporary workspace on the bank. Water remaining in the tube was then allowed to slowly drain by gradually loosening one of the caps. Once all water was drained, the cap was removed and the baffle tray slowly removed from the PVC tube. The sediment in the tray was then transferred into a pre-cleaned 2.5-gallon-size glass jar via a large pre-cleaned stainless steel funnel and stainless steel spoon. A pre-cleaned Teflon® squirt bottle filled with laboratory reverse osmosis water was used to wash any remaining sediment from the tray into the sample jar. In addition, sediment that had settled within the tube, but outside of the tray, was also collected by rinsing the tube with laboratory reverse osmosis water from a squirt bottle. The sample jar was capped with a Teflon® lined lid, labeled with the appropriate location information and put in a cooler with ice and a plastic barrier for delivery to KCEL. Upon receipt at KCEL, the sample was logged, homogenized and transferred to appropriate sample containers for the various analyses. Samples were stored per the SAP until analysis.

One baffle trap equipment blank was collected by filling the PVC housing containing the trap with reverse osmosis reverse osmosis laboratory water. The trap was sealed with caps placed on the inlet and outlet openings. This was allowed to sit for 2 to 3 days. The laboratory water was then collected into appropriate sample jars and analyzed for SVOCs.

### 2.2.1.2 Jar Sediment Trap

Jar-style traps consist of two wide-mouth 1000 mL Teflon® bottles with the following dimensions: 3.5 inch diameter, 7.75-inch height (7 inches to shoulder) with a 1 5/8-inch opening. The bottles are attached to a concrete block (6 inches in height) (Appendix C). Once inserted into the concrete block, the top of the collection bottle is approximately 9 inches above the stream bed.

Upon retrieval of the jar traps, the sample containers were capped and removed from the concrete block and put on ice in a cooler for delivery to KCEL. Upon receipt at KCEL, the samples were logged and then allowed to sit for 1-2 days to allow fines to settle; excess water was decanted and siphoned off. When necessary, the sample was centrifuged to further reduce the water content. Once the overlying water was removed, a pre-cleaned stainless steel spoon or spatula was used to homogenize the sample and transfer it to appropriate sample containers for the various analyses. Samples were stored per the SAP until analysis.

### 2.2.2 Suspended Solids Characterization – Filtered Solids

The filtered solids sampling strategy was designed to collect suspended solids samples to characterize a baseflow and various storm event conditions. The filtered solids samples were collected with purpose-built devices obtained from the Washington State Department of Ecology. The devices pump water through 20-inch long, 4-inch diameter 5 micron bag-type polypropylene felt filters to trap suspended solids. The system consists of a DC-powered bilge pump connected to a frame, which supports two parallel filtration housings. Batteries are placed adjacent to the frames and connected via waterproof cable. Water is pushed through a one-inch diameter, reinforced PVC hose where the flow is split and forced through two independent filter canisters. Flow totalizers connected to the outflow side of each filter canister measured the volume of water passing through each filter; thus, the volume of water pumped through the filter over the sampling period was estimated and recorded. Photos of the sampling equipment are presented in Appendix C.

At most sites, one baseflow and five storm events were sampled. At the Black River and Springbrook Creek sites (results presented together), samples were collected during two baseflow and five storm events. At the Green River–Foster Links location, three baseflow and nine storm event samples were collected to allow additional characterization at the most downstream sampling location under different flow conditions. The storm events were triggered by a minimum of 0.25 inches of rain without an antecedent dry period

requirement. To the extent possible, storms of varied intensity were targeted. Samples were typically collected over a 20- to 24-hour period. Due to the low suspended solids concentrations during the baseflow events, multiple sampler units were deployed. In five of ten baseflow sampling events, the samplers were deployed for 2-3 days rather than 1-day to obtain sufficient mass for analysis. In addition, during a few storm events, sample collection times were less than the targeted 24-hour timespan due to turbid river or creek conditions that caused the filter bags to become plugged.

At the end of each sampling event, the filtration units were retrieved from the site. Valves in the bottom of the filtration housings were opened to allow remaining filtrate to drain. The entire unit was then transported back to KCEL. At the laboratory, filter bags were removed from the filter housings, gently squeezed of their excess water, and placed into Ziploc<sup>®</sup> plastic bags and labeled with the sample location name, filtered volume, and date. These filters were stored at 4 °C. Within a few days of collection, the solids were removed by cutting the filter open and gently scraping the solids from each filter using a pre-cleaned stainless steel spatula. Not all of the captured particles could be removed from the filter, and so there were some fine particles that could not be included in the sample. Solids from all filter bags associated with the sampling location and sampling event were combined into a pre-cleaned clear glass wide-mouth jar and thoroughly mixed. Once homogenized, the solids were split into appropriate sample containers for the various chemical analyses. Samples were stored per the SAP until analysis.

Filtered solids samples were analyzed for PCBs, 17 dioxin/furan congeners, PAHs, arsenic (and other select metals listed in Section 3), total solids and PSD. The filtered solids could not be analyzed for TOC because the filter material created false positives for this analyte. PCBs were initially analyzed as Aroclors<sup>®</sup>, per the SAP, but were subsequently analyzed as PCB congeners (all 209) after experiencing difficulties in detecting Aroclors in most samples. During some events, sample mass was insufficient for analysis of all desired parameters.

Collection and analysis of one equipment blank at KCEL was conducted for the filter bags used to collect filtered solids. The equipment blank was used to evaluate levels of contamination that might be associated with the filter bags. The filter bag was soaked in reverse osmosis laboratory water for approximately 6 days. The water was placed into appropriate sample jars and analyzed for metals, PAHs and TOC.

## 2.3 Sampling Events

The original scope for collection of sediment trap samples included two wet season deployments at all sites except the Black River location: Period 1 (fall/winter 2012-13) and Period 2 (spring 2013). Additional funding became available to collect samples during a third (Period 3 - summer 2013) and fourth deployment (Period 4 -fall/winter 2013-14). Following review of the filtered solids data from the Black River Pump Station, a sediment trap was also deployed in Springbrook Creek during Period 4. While the intent of sample collection during Period 3 was to assess dry season conditions, a very large storm occurred at the end of the deployment period (rainfall from 09/28/13 through 09/30/13 totaled 3.5

inches at the TUKW gage). As such a fifth deployment (Period 5 - summer 2015) was conducted at all six locations to better characterize dry season conditions. Table 2-2 lists the sediment trap sample period, sediment trap type, and sample identification number for each location.

			Sediment Tra	p Collection Per	iod/Sample II	כ
Sediment Trap Type	Location	<b>Period 1</b> Oct 2012 – Feb 2013	<b>Period 2</b> Feb 2013 – May 2013	<b>Period 3</b> July 2013 – Sept/Oct 2013 <sup>a</sup>	<b>Period 4</b> Oct 2013 – Jan 2014	<b>Period 5</b> July 2015 – Sept 2015
	Green River– Flaming Geyser	L57305-1	L57986-1	L58785-1	L59454-1	L63466-1
	Newaukum Creek	L57305-3	L57986-3	L58785-3	L59454-3	L63466-3
Baffle	Soos Creek	L57305-4	L57986-4	L58785-4	L59454-4	L63466-4
	Mill Creek	L57305-5	L57986-5	L58785-5	L59454-5	L63466-5
	Springbrook Creek				L59454-7	L63466-7
	Green River– Foster Links	L57305-2	L57986-2	L58785-2	L59454-2	L63466-2
Jar	Mill Creek	L57305-6				
	Green River– Foster Links		L57986-6	L58785-6	L59454-6	L63466- 6
<sup>a</sup> Period 3 tra during the s	aps retrieved in Sep ame week. Specific	otember or Oct retrieval dates	ober 2013. Hig s listed in Appe	h flows prevente ndix D.	d safe retrieva	l of all traps

Table 2-2.	Sediment trap sample identifications by location, collection period and sample
	type.

Filtered solids were collected between 2012 and 2015 at seven locations. At both main stem sites and at each tributary basin, one baseflow sample and at least five storm samples were collected<sup>7</sup>. While there was minimal rainfall within 24 hours of any baseflow sample (<0.04 inches), samples collected in October through December may be more representative of wet baseflow conditions. Storm samples were collected between October and April during rain events. Table 2-3 lists the collection date, sample identification number, and the flow condition for all samples collected at each location.

<sup>&</sup>lt;sup>7</sup> While conditions are unique between Springbrook Creek and the Black River sites, samples collected from both sites are often discussed together as representing the Black River/Springbrook Creek basin.

Location	Flow Type	Collect Date	Sample ID
	Baseflow	9/10/2013	L58754-1
	Storm	3/20/2013	L57634-3
Green River–	Storm	4/4/2013	L57732-3
Flaming	Storm	4/18/2013	L57792-2
Oeysei	Storm	3/5/2014	L59919-2
	Storm	4/16/2014	L60187-1
	Baseflow	10/22/2013	L59049-1
	Storm	11/7/2013	L59190-2
Newaukum	Storm	1/8/2014	L59472-1
Creek	Storm	1/28/2014	L59596-1
	Storm	2/11/2014	L59723-2
	Storm	2/18/2014	L59723-4
	Baseflow	10/16/2013	L58977-1
	Storm	2/22/2013	L57495-4
Soos Creek	Storm	4/4/2013	L57732-2
SOOS CIEEK	Storm	4/18/2013	L57792-3
	Storm	11/7/2013	L59190-1
	Storm	1/8/2014	L59472-3
	Baseflow	8/13/2013	L58537-1
Mill Creek	Storm	2/22/2013	L57495-5
	Storm	3/20/2013	L57634-2
	Storm	1/29/2014	L59596-2
	Storm	2/12/2014	L59723-1
	Storm	2/18/2014	L59723-3
	Baseflow	10/7/2014 <sup>a</sup>	L61510-1
Black River	Baseflow	12/9/2013 and 12/18/2013 <sup>b</sup>	L59457-1
	Storm	10/22/2014	L61568-2
	Storm	11/24/2014	L62291-2
	Storm	12/9/2014	L61838-1
Springbrook	Storm	4/16/2014	L60187-2
Сгеек	Storm	10/26/2015	L64107-1
	Baseflow	8/19/2013° 6/22/2045°	L58537-2
	Baseflow	0/22/2015ª	L03101-1
	Storm	2/22/2013	L03030-1
	Storm	3/20/2013	L57634-1
Croop Divor	Storm	<i>4/4/</i> 2013	L57732-1
Foster Links	Storm	4/18/2013	L 57792-1
	Storm	3/5/2014	L59919-1
	Storm	10/22/2014	L61568-1
	Storm	11/3/2014	L62291-1
	Storm	10/10/2015	L63997-1
	Storm	11/14/2015	L64265-1
<sup>a</sup> Samples collect <sup>b</sup> Samples from t	ed over 36 to 72 hour tir wo sample events comb	ne span to obtain sufficient mass (se ined to provide sufficient mass for ar	ee Table 2-6). nalysis.

#### Table 2-3. Filtered Solids sample identifications by location, collection date, and flow type.

### 2.3.1 Precipitation and Flow

Precipitation and flow information for the sample periods for each sample location are presented here. Table 2-4 lists the precipitation and flow gages used for each sample location.

Location	King County Precipitation Gage	Flow Gage					
Green River – Flaming Geyser	40U	USGS 12105900					
Newaukum Creek	40U	USGS 12108500					
Soos Creek	32U	USGS 12112600					
Mill Creek	SEQU	King County 41C <sup>a</sup>					
Black River/Springbrook Creek	TUKW	n/a					
Green River–Foster Links	TUKW	USGS 12113000					
<sup>a</sup> Unlike other locations, this gage is approximately 7 miles upstream of Mill Creek sampling location and only provides relative flow estimates when comparing results between events at Mill Creek. These flow data are only appropriate for relative comparison across events, not to estimate relative magnitude compared to other locations. n/a – not available							

 Table 2-4.
 Precipitation and flow gages associated used for each sampling location.

Table 2-5 summarizes the precipitation and flow conditions for each sediment trap sampling period. As noted above, a large storm occurred before the Period 3 (summer 2013) sediment traps were retrieved. The sample collected during Period 5 (summer 2015) represents more typical dry season conditions. An average of 2.7 inches of rain fell at all locations during Period 5, compared to an average of 10.9 inches during Period 3. Period 1 (fall/winter 2012-13) experienced the highest total rainfall (average 19.2 inches) of all the sampling periods.

Table 2-5.	Rainfall and flow data for each sediment trap sampling event.
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		Deploy Duration		Precipitation (inches)			Daily Average Flow (cfs)		
Location	Period	Date	(days)	Daily Average	Total	Percentage of Days with Precipitation	Minimum	Maximum	Average
	1	10/29/12	108	0.18	20.0	81%	420	3,439	1,250
Crean Diver	2	02/21/13	82	0.16	13.2	57%	717	3,318	1,691
Green River-	3	07/03/13	89	0.12	10.4	37%	251	1,538	349
rianning Geyser	4	10/08/13	91	0.10	9.39	56%	439	4,818	1,195
	5	06/04/15	103	0.03	3.33	16%	182	257	216
	1	10/29/12	98	0.20	19.4	82%	31	191	84
News	2	02/14/13	89	0.15	13.3	55%	39	323	69
Newaukum	3	07/03/13	97	0.12	11.9	39%	18	102	25
Cleek	4	10/16/13	83	0.11	8.85	58%	22	146	45
	5	06/04/15	103	0.03	3.33	16%	12	34	17
	1	10/29/12	98	0.20	19.3	81%	96	391	225
	2	02/14/13	89	0.12	11.2	51%	113	516	197
Soos Creek	3	07/03/13	97	0.13	13.0	36%	22	341	61
	4	10/16/13	83	0.10	8.30	58%	51	236	113
	5	06/04/15	62	0.00	0.14	11%	20	43	33

		Doploy	Duration		Precipitati	on (inches)	Daily	Average Flow	(cfs)
Location	Period	Date	(days)	Daily Average	Total	Percentage of Days with Precipitation	Minimum	Maximum	Average
	1	10/29/12	98	0.19	19.1	83%	2.53	26.0	9.85
	2	02/14/13	89	0.11	10.1	51%	1.56	33.8	6.01
Mill Creek <sup>a</sup>	3	07/03/13	97	0.11	10.8	32%	0.26	39.9	3.09
	4	10/16/13	83	0.08	6.95	58%	1.25	267	3.10
	5	08/05/15	41	0.07	2.99	29%	0.15	12.4	0.75
Springbrook	4	10/16/13	83	0.08	6.44	54%	_	-	-
Creek	5	06/04/15	103	0.03	3.30	17%	-	_	-
	1	11/08/12	98	0.18	18.1	71%	755	3,372	1,722
<b>a b</b> ;	2	02/27/13	76	0.12	9.39	47%	1069	4,591	2,346
Green River– Foster Links	3	07/03/13	89	0.09	8.15	28%	281	2,060	420
	4	10/16/13	83	0.08	6.44	54%	560	5,339	1,588
	5	06/04/15	103	0.03	3.30	17%	226	425	278

<sup>a</sup> Flow estimated from meter approximately 7 miles upstream of sample location. Flow data are presented to provide relative comparison between Mill Creek sampling events; data do not provide accurate flow for where sample collected.

While tributary storm flows are primarily influenced by local runoff during storm events, the main stem locations are also influenced by water releases from the Howard Hanson Dam. Flows greater than 2,000 cubic feet per second (cfs) at the gage below the dam (USGS Gage 12105900) are considered significant dam releases for purposes of this report. Period 2 (spring 2013) experienced the most days with average flows greater than 2,000 cfs (29 out of 82), compared to Periods 3 (summer 2013) and 5 (summer 2015), when average daily flows never exceeded 2,000 cfs. Average daily flows exceeded 2,000 cfs during Periods 1(11 days) and 4 (15 days). However, Period 1 experienced the highest average flow and most rainfall of the sampling periods. Section 6.3.2 presents a comparison of chemical concentrations and physical characteristics for each sample to average flows during the deployment period.

Table 2-6 summarizes flow and rainfall during each filtered solids sampling event. During storm events, rainfall (including 12 hours prior to, and during sampling) ranged from 0.17 to 1.8 inches across all locations. Appendix E shows graphs of flow and rainfall at each site over the study period. Significant dam releases (>2,000 cfs at the USGS gage below the dam) occurred during two main stem sampling events (Table 2-6). On 03/05/2014, flow was not recorded at the gage below the Howard Hanson Dam; however, interpolation using the downstream USGS Gage (12113000) near Auburn and rainfall data indicates significant releases occurred throughout the sampling event. Section 8.3 compares chemical concentrations and physical characteristics of each sample to average flows during the sample period.

		Time	Total Rainf	Flow (cfs)			
Location	Start Date/Time	Span (hrs.)	12 Hrs. Prior to Sampling	During Sampling	Min	Max	Average
	03/20/13 11:00	24	0.46	0.14	1550	1,720	1,697
	04/04/13 13:30	22	0.05	1.04	1960	2,170	1,967
Green River– Flaming Geyser	04/18/13 15:25	20	0.01	1.01	1120	1,810	1,265
	09/10/13 14:00	43	0.00	0.00	253	300	294
	03/05/14 12:00 <sup>a</sup>	24	0.70	1.04	NA <sup>b</sup>	NA <sup>b</sup>	NA <sup>b</sup>
	04/16/14 12:30	24	0.28	0.84	1,020	1,490	1,146
	10/22/13 13:30	22	0.01	0.02	22	23	22
	11/07/13 13:10	23	0.68	0.22	61	94	78
Newaukum Creek	01/08/14 13:20	22	0.13	0.32	73	117	98
Newaukum Creek	01/28/14 13:45	21	0.00	1.10	42	137	70
	02/11/14 12:15	22	0.01	0.42	71	102	83
	02/18/14 13:20	22	0.06	0.11	359	605	431
	02/22/13 11:55	20	0.35	0.12	149	170	165
	04/04/13 14:45	21	0.09	0.71	111	164	128
Soos Creek	04/18/13 16:20	20	0.01	0.90	252	315	269
	10/16/13 13:15	21	0.00	0.00	81	82	81
	11/07/13 11:10	24	1.11	0.27	155	180	171
	01/08/14 11:30	24	0.05	0.43	166	216	203
	02/22/13 10:50	8	0.30	0.22	4.82 °	6.55 °	5.57 °
	03/20/13 09:35	8	0.48	0.13	10.27 °	12.58 °	11.29 °
Mill Creek	08/13/13 13:30	21	0.00	0.00	0.21 °	0.40 °	0.29 °
	01/29/14 09:30	23	0.95	0.51	7.07 °	11.8 °	9.93 °
	02/12/14 09:10	3.5	0.25	0.00	11.19 °	12.44 °	11.91 °
	02/18/14 10:40	26	0.12	0.63	43.5 °	59.32 °	49.92 °
	12/09/13 11:20 °	22.75	0.00	0.00	NA	NA	NA
	12/18/13 11:30 °	<21	0.04	0.00	NA	NA	NA
Black River	04/16/14 15:00 (SC)	12	0.34	0.27	NA	NA	NA
(and Springbrook	10/07/14 16:00	48	0.00	0.00	NA	NA	NA
Creek = SC)	10/22/14 11:30	24	0.71	0.80	NA	NA	NA
	12/00/14 00:45	20.25	0.00	0.59			
	12/09/14 09.45 10/26/15 11:30 (SC)	24	0.10	0.56		NA NA	
	02/22/13 00:50	22	0.37	0.00	1 200	1 550	1 420
	02/22/13 03.30 03/20/13 13:00 ª	23	0.40	0.06	2 330	2 500	2 401
	04/04/13 15:45 ª	24	0.15	0.50	2,330	2,000	2,401
	04/18/13 16:50	22	0.03	0.67	1 750	2,400	1 944
	08/19/13 14:30	40	0.00	0.00	299	307	303
Green River-	03/05/14 10:00 ª	21	1.08	0.73	5.580	7.920	6.652
Foster Links	10/22/14 10:00	24	0.36	1.14	936	1.490	1.241
	11/03/14 14:30	19.5	0.07	0.46	1,410	1,820	1.671
	06/22/15 10:00	72	0.00	0.00	295	312	303
	09/22/15 14:15	36	0.00	0.00	329	415	381
	10/10/15 13:45	21	0.71	0.54	508	581	559
	11/14/15 12:30 ª	12	1.07	0.73	7,130	7,520	7,373

#### Table 2-6. Rainfall and flow data for each filtered solids sampling event.

Note: Flows are based on 15-minute flow readings. "Average" refers to the average of the 15-minute flow over the duration of the sampling event.

<sup>a</sup> Significant dam releases occurred during sampling event (>2,000 cfs at USGS gage below Howard Hanson Dam).

<sup>b</sup> Flow meter failed for this event, average flow approx. 4,000 cfs.

<sup>c</sup> Flows estimated from gage approximately 7 miles upstream of sampling location and should only be used for relative comparisons between Mill Creek events, not between sites.

<sup>d</sup> Samples were combined to represent one baseflow sample (L59457-1).

**Bold text** indicates baseflow sample.

### 2.4 Field Sampling Deviations from the SAP

All field sampling methods were conducted according to the SAP (King County 2013c) except where noted below.

#### **Sediment Traps**

In addition to the sampling proposed in the SAP, traps were deployed for a third, fourth and fifth sampling period. An additional sampling location (Springbrook Creek) was added during the fourth and fifth deployment periods. The jar-style trap was only deployed at Mill Creek for one period rather than the two periods specified in the SAP; however, it was deployed at Green River–Foster Links location for the remaining sampling periods. These deviations are not expected to have an adverse effect on the study.

The SAP specified the equipment blank for the baffle housing would be analyzed for metals/mercury, SVOCs and PCB Aroclors. However, the equipment blank was only analyzed for SVOCs because the PVC housing was not expected to be a source of the other chemicals.

As part of the quality assurance effort proposed in the SAP, the field crew periodically checked the sediment traps during the deployment period. The following situations were observed during these field inspections:

- On January 3, 2013 the field crew found the baffle sediment trap at Green River– Foster Links turned on its side. The entire unit was still facing upstream, mostly level and in proper orientation. It is believed a log or some debris might have hit the trap or the line used to secure the trap and caused it to turn on its side. A brief inspection found material still in the trap and the trap was moved back into position. It is unclear how much material may have been lost from the trap when it was turned on its side. This event may or may not have influenced the baffle sediment trap results for Period 1 at Green River–Foster Links.
- On July 8, 2105, the water level at Mill Creek was extremely low such that there was no visible flow and the baffle trap was no longer underwater. The trap was checked on August 5, 2015, however, it was still above the water level so it was retrieved and the sample was collected at this time. At the time of retrieval, standing water covered the sample inside the baffle sediment trap. Therefore, while the equipment was out of the water, the sample itself was not directly exposed to the air.

- On July 8, 2015, the water level at Green River Flaming Geyser was very low and the field crew found the baffle trap had been tampered with and partially removed from the water. The field crew re-deployed the trap slightly downstream and in the deepest water available, while still ensuring it could be safely retrieved if water levels increased. The trap was armored along its sides with large rocks to reduce the chance of additional tampering.
- On July 8, 2015, the water levels at Newaukum Creek were very low and the baffle trap had been cut loose from the blocks; it was found a few hundred feet downstream of the original location. The trap was removed and redeployed on August 8, 2015. No sample material was retrieved in July; sample material is from the new deployment date of August 5 till retrieval in September.

It is uncertain what effect these issues had, if any, on the data quality; however, concentrations of more volatile compounds, like LPAHs, may have been impacted in the Mill Creek trap in summer 2015, because the trap was out of the water for an unspecified time.

### **Filtered Solids**

The project SAP specified baseflow samples would be collected during the dry season; however, some were collected after the wet season had started. The site hydrographs suggest baseflow samples collected after September may be more representative of wet baseflow conditions; however, none of these samples were collected within 24 hours of appreciable rainfall (Table 2-6).

The SAP indicated that filter bags would be weighed prior to and following use; however, this step was not taken because the weight measurement was not necessary. Initially it was anticipated that the entire filter bag would be extracted. However, prior to sampling it was determined that extraction of the filter bags resulted in significant analytical interference.

During some of the multi-day baseflow sampling events, it was necessary to replace the filter bags in the field due to the filter being partly plugged. In these instances, the bags were removed from the canisters on site and excess water was gently squeezed from them. The filter bags were then placed in Ziploc<sup>®</sup> bags and transported to KCEL in coolers with ice. A new filter bag was installed in each canister and the unit was restarted.

The SAP deviations associated with collection of filtered solids samples are not expected to have an adverse effect on the study.
## 3.0. LABORATORY METHODS

This section presents a summary of the laboratory analyses performed on all samples. Laboratory analyses were conducted by KCEL, except PCB and dioxin/furan congeners, which were analyzed by AXYS Analytical Services, Ltd and Pacific Rim Laboratories.

The KCEL reports both the reporting detection limit (RDL) and the method detection limit (MDL) for each sample and parameter, where applicable. A high resolution isotopic dilution based method is used for analysis of PCB and dioxin/furan congeners where the MDL and RDL terms are less applicable because limits of quantitation are derived from calibration capabilities and ubiquitous, but typically low level equipment and laboratory blank contamination. Thus, PCB congener data are reported to lowest method calibration limits (LMCLs). Values below this are flagged as estimated down to the sample specific detection limit (SDL) value. The following sections provide a summary of the laboratory methods; greater detail can be found in the project SAP (King County 2013c).

### 3.1 Conventional Parameters

TOC in sediment trap samples was analyzed using the EPA SW846 9060-PSEP96 method. Total solids in all samples were analyzed by Standard Methods 2540-G.

Particle size distribution followed ASTM D422 method, using a wet sieve and hydrometer, when sufficient mass was available (most sediment trap samples) and results are given in percent mass. When mass was insufficient to conduct standard PSD analyses (some sediment trap samples and all filtered solids samples), PSD was quantified by a combination of sediment concentration (PSD-SC) by ASTM D422/D3977-97 and laser diffraction (PSD-LD) methods by ISO 13320:2009(E). The PSD-SC was used to determine percent mass greater than 500 microns (µm). The PSD-LD estimates percent volume of particles less than 500 µm. While these methods result in different units (% mass for ASTM methods and % volume for laser diffraction method), the mass to volume ratio (i.e., density) of these particles should be fairly similar between the size fractions. Therefore, the difference in units (% mass versus % volume) should not appreciably impact the overall results<sup>8</sup>. A potential exception is when the sample contains a large amount of organic matter, because organic matter tends to have a lower density than other sediment particles. In samples with large amounts of organic matter, particles greater than 500 µm (gravel/large sand) could contribute relatively less of the samples' volume than the samples' mass. This is because the lighter organic matter is contributing more to the volume of the fines size class than to its mass. In these cases, combining the percent mass of the gravel/large sand particles with the percent volume of the smaller size classes, could overestimate the contribution of the gravel/large sand particle size class. However, for

<sup>&</sup>lt;sup>8</sup> Particle density does not directly relate to size class, but instead to mineral type. A common approximation of particle density is 2.65 g/cm<sup>3</sup>, because this is the density of quartz and feldspar, which are common minerals in sediment. Most minerals have fairly similar particle density (e.g., sandstone density = 2.1 g/cm<sup>3</sup> and basalt density = 3.3 g/cm<sup>3</sup>), with the exception of iron (7 g/cm<sup>3</sup>). Organic matter (humus) has a relatively low density of less than 1.5 g/cm<sup>3</sup> (Bunte and Abt 2001).

most samples, particles greater than 500  $\mu$ m comprised less than 5% of the mass, and so combining the PSD-SC and PSD-LD results should provide a reasonable estimate of PSD in most cases and introduce only low levels of uncertainty into the results.

There are similar issues when comparing between the more traditional ASTM D422 PSD method (% mass) and the combined PSD-SC/PSD-LD methods (mostly % volume). As described above, most particles have similar densities across size classes with the exception of samples with large amounts of organic matter. Another difference between the PSD methods is the binning of phi sizes. Table 3-1 illustrates the differences between these methods.

Phi Size	Millimeters	ASTM PSD	PSD-SC and PSD-LD				
p <-2.00	>4,750	Gravel	>500 µm				
p -2.00	4,000 to <4,750	(% mass)	(% mass)				
p -1.00	2,000 to <4,000						
p 0.00	1,000 to <2,000	Sand					
p +1.00	500 to <1,000	(% mass)	а				
p +2.00	250 to <500		Sand				
p +3.00	125 to <250		(% volume)				
p +4.00	62.5 to <125						
p +5.00	31 to <62.5	Silt	Silt				
p +6.00	16 to <31	(% mass)	(% volume)				
p +7.00	8 to <16						
p +8.00	4 to <8						
p +9.00	2 to <4	Clay	Clay				
p +10.0	1 to <2	(% mass)	(% volume)				
p ≥+10.0	<1						
<sup>a</sup> There is overlap within the p +1.00 phi size range, because non-spherical particles may pass through the sieve, and later register as >500 $\mu$ m during the PSD-LD method. The +1.00 phi size particles comprise between <mdl 3.6%="" 6.63%="" <mdl="" and="" filtered="" for="" not<="" overlap="" samples="" samples.="" sediment="" should="" solids="" td="" the="" therefore,="" this="" to="" trap=""></mdl>							

#### Table 3-1. Krumbein phi sizes utilized in the ASTM PSD method versus the combined sediment concentration (PSD-SC) and laser diffraction (PSD-LD) methods.

substantially influence conclusions drawn from the PSD results.

Three baffle trap samples were analyzed for PSD using the PSD-SC and PSD-LD, while the rest were analyzed using the traditional ASTM PSD method. As such, there is some uncertainty in comparison of PSD across all baffle trap samples. All filtered solids samples were analyzed using the PSD-SC and PSD-LD methods, so while there is some uncertainty in the percentage of particles between 1,000 and 500 µm, and the exact contribution of the gravel/large sand particles, PSD results for the filtered solids samples are generally comparable, especially for fines.

### 3.2 Metals and Mercury

The primary inorganic element analyzed in this study was arsenic. However, because the analytical method and sample mass is the same for other inorganic elements, the analysis also included cadmium, chromium, copper, lead, nickel, silver, vanadium and zinc. The metals samples were prepared and analyzed by EPA Method 3050B / 6020A (Inductively Coupled Plasma-Mass Spectrometry [ICP-MS]). When mercury was analyzed, EPA Method 7471B (Cold Vapor Atomic Absorption [CVAA] was used.

### 3.3 PAHs and other Semi-Volatile Compounds

The primary SVOCs analyzed in this study were PAH compounds (Table 3-2). However, when sufficient sediment trap sample mass was available a number of additional SVOCs (those with marine sediment quality standards), such as phthalates, phenolic compounds and chlorobenzene compounds (see Appendix D) were also analyzed. The samples were prepared by sonication extraction as detailed in method SW846 3550B, and analyzed by method SW846 8270D. PAHs in filtered solids samples were prepared using the same method, but were analyzed using the Selected Ion Monitoring (SIM) method (SW846 8270 D SIM). The MDL and RDL goals for this method are also presented in Table 3-2 (These were not established before completion of the SAP). The MDL/RDL goals were only met 16 percent of the time due to the limited sample mass collected. Ten to 30 g of sample material was used for extractions, depending upon the amount collected.

PAH Analyte	MDL-FS	RDL-FS	MDL-SIM	RDL-SIM
2-Methylnaphthalene	5.3	10.7	1.07	5.33
Acenaphthene	5.3	10.7	0.53	2.67
Acenaphthylene	5.3	10.7	0.53	2.67
Anthracene	5.3	10.7	0.53	2.67
Benzo(a)anthracene	5.3	10.7	0.53	2.67
Benzo(a)pyrene	5.3	10.7	0.53	2.67
Benzo(b,j,k)fluoranthene	5.3	10.7	0.53	2.67
Benzo(g,h,i)perylene	5.3	10.7	0.53	2.67
Chrysene	5.3	10.7	0.53	2.67
Dibenzo(a,h)anthracene	5.3	10.7	0.53	2.67
Dibenzofuran	5.3	10.7	0.53	2.67
Fluoranthene	5.3	10.7	0.53	2.67
Fluorene	5.3	10.7	0.53	2.67
Indeno(1,2,3-Cd)Pyrene	5.3	10.7	0.53	2.67
Naphthalene	5.3	10.7	0.53	2.67
Phenanthrene	5.3	10.7	0.53	2.67
Pyrene	5.3	10.7	0.53	2.67
Note: MDL/RDL limits are calcu volume of 1.0 mL with a 3/8 los	llated on an e s for GPC cle	extraction of 3 eanup. MDL/F	30 grams to a RDL limits wil	i final I vary

## Table 3-2.Polycyclic aromatic hydrocarbon compounds and detection limit goals by SIM<br/>(μg/kg ww).

PAH Analyte	MDL-FS	RDL-FS	MDL-SIM	RDL-SIM			
depending on amount extracted and final volume.							
FS-full scan; SIM- Selected Ion	Monitoring						

#### 3.4 Pesticides

Although not specified in the SAP, a few samples were analyzed for organochlorine pesticides. These were prepared and analyzed by EPA Method SW846 3550B/8081B. The samples analyzed for pesticides and the specific analytes can be found in Appendix D.

### 3.5 PCBs

The SAP specified that PCBs would be analyzed as Aroclors according to EPA methods 3550B/8082A (SW846), which employs solvent extraction with sonication and analysis by Gas Chromatography – Electron Capture Detector (GC/ECD) and dual column confirmation. MDLs for Aroclors ranged from approximately 2 to 7  $\mu$ g/kg dry weight depending on the sample and Aroclor. The first few rounds of sample analysis resulted in largely non-detected results. A decision was made to analyze the remainder of the samples using a congener method to achieve lower detection limits.

Samples were analyzed for all 209 PCB congeners following EPA Method 1668C (EPA 2010a), which is a high-resolution gas chromatography/high-resolution mass spectroscopy method using an isotope dilution internal standard quantification. For most samples, AXYS Analytical performed the analysis according to their standard operating procedure (SOP) MLA-010 Analytical Method for the Determination of 209 PCB Congeners by EPA Method 1668, which is a proprietary document. The sample was extracted, followed by standard method clean-up, which includes layered Acid/Base Silica, Florisil and Alumina. Analysis was performed with an SPB Octyl column. Pacific Rim Laboratories<sup>9</sup> analyzed 7 sediment traps and 10 filtered solids samples according to their SOP LAB02. The sample was extracted followed by standard method clean-up, which includes layered with an SPB Acid Silica, Carbon, and Alumina column chromatography. Analysis is performed with an SGE HT-8 column.

### 3.6 Dioxin/Furan Congeners

Samples were analyzed for 7 dioxin and 10 furan congeners. Dioxin/furan congener analysis was performed according to EPA Method 1613B (EPA 1994), which is a highresolution gas chromatography/high-resolution mass spectroscopy method using an isotope dilution internal standard quantification. For most samples AXYS Analytical performed this analysis according to their SOP MLA-017. Samples were extracted using either sonication or soxhlet. Pacific Rim Laboratories analyzed 7 sediment trap and 8 filtered solids samples according to their SOP PRL-LAB01/GC-HRMS. Both laboratory SOPs

<sup>&</sup>lt;sup>9</sup> King County's contract with AXYS Analytical expired before all samples were analyzed. The new contract lab, Pacific Rim Laboratories, analyzed the remaining samples.

are based on EPA Method 1613b Tetra- through Octa-Chlorinated Dioxins and Furans by Isotope Dilution HRGC/HRMS. Samples were extracted followed by standard method cleanup, which includes layered Acid/Base Silica, Florisil, and Alumina.

### 3.7 Analytical Deviations from the SAP

All analytical laboratory methods followed those described in the SAP with the following exceptions:

- One laboratory triplicate sample per batch was specified in the SAP for TOC, total solids and PSD analyses. However, when sample mass was insufficient only a laboratory duplicate was analyzed, which still provided a measure of precision. In a few cases, there was insufficient mass to run lab duplicates and the data were qualified appropriately.
- PCBs were originally specified to be analyzed as Aroclors. However, after evaluation of data from the first few sampling events, a decision was made to analyze PCBs as congeners by EPA Method 1668C. This is a high resolution method that results in lower detection limits. This change will not adversely affect the quality of the data analysis.
- Pesticides were not specified in the SAP, but were analyzed in a few samples. The additional data will not adversely affect the quality of the data analysis.

## 4.0. DATA ANALYSIS

The analytical data were prepared for data analysis by applying rules for determining PAH, PCB and dioxin/furan sums, as well as total dioxin toxicity equivalents. The details of these calculations, as well as a summary of data analysis methods, are described below.

#### 4.1 Summation for PAHs, PCBs and Dioxins/Furans

In addition to reporting the individual PAH results, the total high molecular weight PAHs (HPAHs) and total low molecular weight PAHs (LPAHs) are reported as the sum of detected HPAHs or LPAHs, respectively. If no PAHs were detected within the LPAH or HPAH class, the reported MDL for these totals is the highest MDL reported for the individual PAHs in that class. LPAHs were calculated as the sum of acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, and phenanthrene. HPAHs were calculated as the sum of benzo(a)anthracene, benzo(g,h,i)perylene, benzo(a)pyrene, benzo(b,j,k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)perylene, and pyrene.

To compare to LDW sediment cleanup goals (see Section 4.2), cPAHs (carcinogenic polycyclic aromatic hydrocarbons) were calculated using potency equivalency factor (PEF) values (California EPA 2002; Ecology 2001) based on the individual PAH component's relative toxicity to benzo(a)pyrene.<sup>10</sup> The PAHs and corresponding PEF values included in this calculation are reported in Table 4-1. The reported concentration for each cPAH in a given sample is multiplied by the PEF and summed, resulting in the cPAH TEQ (toxicity equivalents). If the reported concentration for a given PAH is non-detect, one half the MDL concentration is used in the calculation.<sup>11</sup>

сРАН	Potency Equivalency Factor Value (unitless)
Benzo(a)pyrene	1
Benzo(a)anthracene	0.1
Benzo(b,j,k)fluoranthene <sup>a</sup>	0.1
Chrysene	0.01
Dibenzo(a,h)anthracene	0.4
Indeno(1,2,3-Cd)pyrene	0.1
<sup>a</sup> Benzo(b)fluoranthene and benzo(k LDW RI, but are included as benzo(k	fluoranthene are included separately in the o,j,k)fluoranthene here.

# Table 4-1.Carcinogenic PAH compounds and corresponding benzo(a)pyrene potency<br/>equivalency factor values.

PCB data are presented as total PCB concentrations. When reporting total PCBs for congener based data, only detected congeners are included in the sum. At least one PCB congener was detected in all samples. When both Aroclor and congener data are available,

<sup>&</sup>lt;sup>10</sup> These are the same PEFs used in the LDW RI (Windward 2010).

<sup>&</sup>lt;sup>11</sup> These summation rules are consistent with the approach described in the LDW RI (Windward 2010).

total PCBs are based on the congener data. This is because Aroclor totals were non-detect with detection limits sufficiently above those of the congener method that the average using non-detects would bias high the resulting value. For samples with only Aroclor results, the detected Aroclors were summed to estimate total PCBs. When no Aroclors were detected, the non-detect value was set equal to highest reporting limit of the Aroclors for that sample.

Total dioxins/furans were based on the sum of detected dioxin/furan congeners. At least one congener was detected in each sample. Dioxin and furan congener data were also converted to TEQs to provide a toxicity-based approach to data interpretation and because LDW cleanup goals for dioxins/furans are presented as total dioxin TEQs. Dioxin and furan congener concentrations were converted to TEQ concentrations based on 2,3,7,8-Tetrachlorodibenzodioxin (2,3,7,8-TCDD) toxicity by multiplying the concentration of an individual congener by its toxicity equivalent factor (TEF) for mammals (from Van den Berg et al. 2006) (Table 4-2). The total dioxin TEQ was based on summing the 17 TEQ values. Whenever a dioxin or furan was not detected, the TEF was applied to the full nondetect value (or U qualified value)<sup>12</sup>.

Dioxins	Toxicity Equivalent Factor	Furans	Toxicity Equivalent Factor
2,3,7,8-TCDD	1	2,3,7,8-TCDF	0.1
OCDD	0.0003	1,2,3,4,6,7,8-HPCDF	0.01
1,2,3,4,6,7,8-HPCDD	0.01	1,2,3,4,7,8,9-HPCDF	0.01
1,2,3,4,7,8-HXCDD	0.1	1,2,3,4,7,8-HXCDF	0.1
1,2,3,6,7,8-HXCDD	0.1	1,2,3,6,7,8-HXCDF	0.1
1,2,3,7,8,9-HXCDD	0.1	1,2,3,7,8,9-HXCDF	0.1
1,2,3,7,8-PECDD	1	1,2,3,7,8-PECDF	0.03
		2,3,4,6,7,8-HXCDF	0.1
		2,3,4,7,8-PECDF	0.3
		OCDF	0.0003

Table 4-2.Dioxin and furan compounds and corresponding 2,3,7,8-TCDD toxicity equivalent<br/>factors applied in calculation of dioxin TEQs.

### 4.2 Comparison to LDW Cleanup Goals

When available, suspended sediment concentrations are compared to the sediment cleanup goals established in the LDW Record of Decision (EPA 2014). These include the point-based benthic cleanup goals and site-wide human health cleanup goals for LDW contaminants of concern. Comparing chemical concentrations in suspended solids to these cleanup goals is intended only as a reference point. The cleanup goals apply to bedded sediment in the LDW at various spatial scales. Suspended solids are not equivalent to the potential exposure

<sup>&</sup>lt;sup>12</sup> For laboratory results qualified as "K" by AXYS or "N" by Pacific Rim, which were re-qualified as U by data validation, the dioxin and furan congener based on the result value (rather than sample specific detection limit) was multiplied by the respective TEF.

duration or pathways of bedded sediment. Sediment concentrations in the areas where the suspended solids settle will be impacted by a variety of physical processes, including mixing with current bed sediment and varied suspension times.

### 4.3 Statistical Analysis

Results for the baffle sediment trap samples are presented as both individual sample results and mean concentrations (Section 5.0). Summary statistics for the filtered solids samples describing minimum, maximum, mean and median concentrations are presented on a location-specific basis for storm event samples because at least five samples were collected at each location (Section 7.0). Only total PCBs based on congener results are included in the data analysis.

Statistical differences were considered between the two main stem Green River sites (Flaming Geyser and Foster Links) for baffle sediment trap and filtered solids results. Statistical differences between tributary locations were evaluated only for filtered solids results. These differences between locations were evaluated using permutation tests. This method compares the differences between means of the original dataset to permutations of the dataset prepared by randomly redistributing the results between groups. This tests how likely the original grouping of the data is driving differences between means. It tests the null hypothesis that the grouping does not matter, testing whether the grouping could be random and the differences between means could be comparable. One of the advantages of this statistical test is that it does not require normally distributed data to test differences between means, and the statistical power is relatively high compared to similar statistical tests.

Spatial comparisons of the baffle trap results included data from all five deployment periods combined, whereas for filtered solids data, only storm event sample results were included in the spatial comparisons. No baffle sediment traps from Springbrook Creek were included in the statistical spatial analysis due to low sample size relative to other sites. These results are presented in Sections 6.2 and 8.2, respectively. All spatial comparison analyses were conducted using R studio software.

Relationships between select chemical and physical parameters were examined using the non-parametric Spearman Rank Order Correlation analysis in Sigma Plot v12.5. Findings from this analysis are presented in Sections 8.2 and 8.3 for filtered solids results, and in Section 9.2 for the comparison between baffle sediment trap and filtered solids samples.

### 5.0. SEDIMENT TRAP RESULTS

This Section presents results for the baffle-style sediment traps deployed in the Green River and four major tributaries over five sampling periods: Period 1 (fall/winter 2012-13); Period 2 (spring 2013); Period 3 (summer 2013); Period 4 (fall/winter 2013-14); and Period 5 (summer 2015). As noted in Section 2.3, traps were only deployed in Springbrook Creek during Periods 4 and 5. Results for the jar-style sediment trap are presented in Appendix D and in Section 9.1.Table 5-1 shows the parameters analyzed in samples at each location.

Parameter	Green River – Flaming Geyser	Newaukum Creek	Soos Creek	Mill Creek	Spring- brook Creek	Green River– Foster Links
PSD	5	5	5	5	2	5
TOC	5	5	5	5	2	5
Metals	5	5	5	5	2	5
Mercury	5	5	5	5	2	5
PAHs	5	5	5	5	2	5
SVOCs	5	5	5	5	2	5
PCB- Aroclors	2	2	2	2	0	2
PCB- Congeners	5	3	3	3	2	5
Dioxin/furans	3	3	3	3	2	3
PSD= particle SVOCs-semi-v	size distribution; T	OC-total organic micals: PCB-pol	carbon; PAF	l- polycyclic a biphenyls	romatic hydro	ocarbons;

Table 5-1.	Number of baffle trap samples analyzed by parameter type at each sample
	location.

### 5.1 Particle Size Distribution

The PSD results for the baffle sediment trap samples are based on three size classes: fines, sand and gravel (Phi size information can be found in Appendix D). Gravel (or >500  $\mu$ m particles for PSD-LD) represented the lowest percentage of material at all sites, with the exception of Newaukum, where fines comprised the smallest fraction in three out of five samples. In most baffle trap samples, sand represented the largest fraction, but in a few cases the fines fraction was largest. As stated in Section 3.1, most sediment trap samples were analyzed by the traditional PSD method, but samples with insufficient mass were analyzed using a combination of PSD-SC<sup>13</sup> and PSD-LD. These methods are not directly

 $<sup>^{13}</sup>$  The analytical method PSD\_SC only identifies all material greater than 500  $\mu m.$ 

comparable (results are % mass for ASTM method vs. % volume for PSD-LD method); Section 3.1 presents a discussion of the method differences. Table 5-2 and Figure 5-1 present PSD results by location and sampling period.

Period	Size Class	Green F – Flam Geys	River ling er	Newaul Cree	kum k	Soc Cree	es ek	Mill C	reek	Spring broo Cree	g- k k	Gree River Foster L	n r– .inks
	Fines	21.8		8.6		4.7		39.0		NC		61.9	
1	Sand	72.3		86.2		91.8		51.6		NC		37.7	
	Gravel	0.6	J	0.7	J	0.1	U	0.3	U	NC		0.389	
	Fines	36.7		4.3		5.6		61.0		NC		17.6	J
2	Sand	56.8		81.4		92.0		41.7		NC		62.7	J
	Gravel	6.51		9.9		0.5	J	0.3	U	NC		0.2	UJ
	Fines	27.2	J	0.6	J	8.5		57.4		NC		47.2	J
3	Sand	70.3	J	64.0		86.3		36.2		NC		33.6	J
	Gravel	2.57	J	33.8		0.2	J	0.4	U	NC		0.4	UJ
	Fines	55.9		3.5	J	14.1		32.0	J	78.5		33.7	
4	Sand	44.9		61.8		80.8		32.7	J	16.7		58.1	
	Gravel	2.1	J	32.7		0.5	J	0.5	UJ	0.4	U	0.2	U
	Fines	38.6	J	28.6	J	67.2	J	74.0	J	78.9	J	68.5	J
5	Sand	57.6	J	67.2	J	28.5	J	18.6	J	24.3	J	35.0	J
	Gravel	1.3	J	1.3	J	0.3	UJ	0.2	UJ	0.4	J	0.2	UJ
Note: Gr	aved hox	es indicat	e com	hined PS		and PSF	)-I D n	nethods	i hazı	nstead (	of the	e tradition	al

 Table 5-2.
 Summary of baffle trap PSD results by site and sampling period (% mass).

Note: Grayed boxes indicate combined PSD-SC and PSD-LD methods used instead of the traditional ASTM PSD method; results are not directly comparable due to unit differences (% volume for particles <500  $\mu$ m) and overlap between sand and gravel size classes. (See Section 3.1).

J – estimated value; U – non-detect value; NC – sample not collected



Figure 5-1 PSD in Baffle Sediment Traps by Sample Period and Site

### 5.2 Total Organic Carbon

Percent TOC was variable and ranged from 0.21 (Newaukum – Period 3) to 9.70%. (Soos – Period 5) (Table 5-3 and Figure 5-2). Results across periods were least variable at Mill and Springbrook creeks. On average, TOC was lowest in Newaukum Creek and highest in Springbrook Creek.

Period	Green River - Flaming Geyser	Newaukum Creek	Soos Creek	Mill Creek	Springbrook Creek	Green River - Foster Links
1	1.76	1.10	0.27	1.79	NC	1.19
2	2.20	0.25	0.95	2.24	NC	0.86
3	3.43	0.21	0.92	2.85	NC	3.09
4	4.06	0.87	2.00	2.78	7.76	1.24
5	4.92	4.98	9.70	2.66	7.65	3.00
Mean	3.27	1.48	2.77	2.46	7.70	1.87
NC – sa	mple not collected					

 Table 5-3.
 Summary of baffle trap TOC results by site and sampling period (% dw).



Figure 5-2. Percent TOC in Baffle Sediment Trap Samples by Site and Period

### 5.3 Metals

All ten metals were detected in every sample, except one Newaukum Creek sample where silver was not detected. Table 5-4 summarizes metals concentrations across location and sampling period.

Metal	Period	Green River - Flaming Geyser	Newaukum Creek	Soos Creek	Mill Creek	Springbrook Creek	Green River - Foster Links
	1	5.30	2.37	1.83	6.21	NC	4.95
	2	9.22	2.30	3.94	10.2	NC	4.79
٨٥	3	8.90	2.49	3.07	11.2	NC	12.0
AS	4	9.44	4.81	4.11	13.5	36.7	5.06
	5	12.7	4.86	13.7	15.3	62.1	17.5
	Mean	9.12	3.37	5.32	11.3	49.4	8.86
	1	0.110	0.078 J	0.054 J	0.250	NC	0.119
	2	0.079 J	0.033 J	0.044 J	0.224	NC	0.059 J
	3	0.128	0.043 J	0.066	0.301	NC	0.255
	4	0.165	0.034 J	0.078 J	0.295	2.23	0.084 J
	5	0.153	0.148	0.255	0.345	2.77	0.347
Cd	Mean	0.127 J	0.067 J	0.100 J	0.283	2.498	0.173 J

 Table 5-4.
 Summary of baffle trap metals by site and sampling period (mg/kg dw).

Metal	Period	Green River - Flaming Geyser	Newaukum	Soos Creek	Mill Creek	Springbrook Creek	Green River -
			Oreen	Oreen	Oreen	Oreen	
	1	13.0	32.1	28.0	14.1	NC	17.8
	2	11.9	15.6	26.8	13.9	NC	14.8
Cr	3	11.9	11.5	26.2	16.4	NC	19.5
	4	13.8	13.8	29.6	16.3	30.3	15.3
	5	14.1	19.5	41.4	18.6	34.5	17.6
	Mean	12.6	18.3	27.6	15.1	30.3	16.8
	1	23.4	15.0	9.74	20.4	NC	18.3
	2	20.9	11.4	10.6	20.6	NC	14.5
Cu	3	18.4	11.7	8.68	17.1	NC	23.7
	4	30.7	10.9	13.6	25.1	57.1	16.3
	5	21.5	20.9	27.1	27.2	57.2	27.4
-	Mean	23.4	12.3	10.7	20.8	57.1	18.2
	1	5.67	2.85	2.31	15.6	NC	5.63
	2	6.35	2.05	3.03	18.2	NC	4.94
Pb	3	7.92	2.50	3.56	22.2	NC	13.7
	4	7.59	1.76	4.28	20.2	37.0	5.33
	5	7.60	6.60	13.3	25.7	48.8	14.3
	Mean	6.88	2.29	3.30	19.1	37.0	7.41
	1	12.0	21.0	21.6	107	NC	17.0
	1	10.9	21.0	20.6	10.7	NC	17.2
NI	2	12.2	14.0	21.0	14.0	NC	14.4
	3	14.0	14.0	27.2	14.9	22.7	10.3
	4	14.2	10.0	37.3 11.8	14.9	22.7	15.4
	Mean	12.3	16.7	326	13.0	24.7	16.3
	Mean	10.2	10.1	02.0	10.0	££.1	10.0
	1	0.070.1	0.037.1	0.025.1	0.0882	NC	0.056.1
	2	0.045.1	0.012 U	0.017.1	0.0875	NC	0.030.1
Αα	3	0.058.1	0.030 J	0.025 J	0 109	NC	0.0809
	4	0.086 J	0.015 J	0.028 J	0.121	0.196	0.042 J
	5	0.071 J	0.049 J	0.087 J	0.138	0.256	0.100
	Mean	0.065	0.024	0.024	0.101	0.196	0.052
	1	48.0	39.6	27.4	34.7	NC	42.2
	2	44.2	26.6	28.6	33.9	NC	34.5
V	3	46.4	29.8	27.4	41.0	NC	46.6
	4	58.8	27.7	29.1	40.8	56.0	36.8
	5	50.8	39.5	44.8	46.9	69.8	46.4
	Mean	49.4	30.9	28.1	37.6	56.0	40.0
	1	57.6	50.4	33.5	92.2	NC	52.5
_	2	58.8	35.8	38.1	95.6	NC	44.3
Zn	3	46.3	32.5	29.0	75.0	NC	71.6
	4	78.1	42.1	48.4	125	571	54.1
	5	66.7	74.6	81.6	128	523	89.2
	Mean	60.2	40.2	37.2	96.9	571	55.6

Metal	Period	Green River - Flaming Geyser	Newaukum Creek	Soos Creek	Mill Creek	Springbrook Creek	Green River - Foster Links
	1	0.0924	0.022 J	0.013 J	0.056 J	NC	0.056 J
	2	0.078 J	0.014 J	0.018 J	0.078 J	NC	0.033 J
Hg	3	0.082 J	0.026 J	0.020 J	0.11 J	NC	0.091 J
•	4	0.153	0.020 J	0.030 J	0.10	0.096 J	0.041 J
	5	0.077 J	0.061 J	0.097 J	0.147 J	0.098 J	0.0977
	Mean	0.101	0.020	0.020	0.085	0.096	0.055
Means U – nor	include no n-detect; J	on-detects at the MD – estimated value; I	L Value NC – sample ne	ot collecte	d		

The highest concentrations of arsenic, cadmium, copper, lead, silver, vanadium, and zinc were detected at Springbrook Creek. The highest metal concentrations were typically detected during the sampling period with the highest percent fines. Section 6.3 further explores the relationship between chemical, conventional and physical parameters.

Metal concentrations were compared to their respective LDW benthic cleanup goals (pointbased goal equal to the Sediment Management Standards marine sediment quality standard) (see Appendix F). Arsenic results were also compared to the site-wide human health LDW cleanup goal of natural background. Zinc concentrations in Springbrook Creek exceeded the point-based benthic cleanup goal (410 mg/kg). The arsenic concentration in one Springbrook Creek sample exceeded the point-based benthic cleanup goal (57 mg/kg), while levels in 13 samples exceeded the site-wide human health cleanup goal (7 mg/kg). Metal concentrations in all other baffle sediment trap samples were below LDW cleanup goals. Figure 5-3 presents arsenic results by location followed by the sample periods, and presents a comparison to LDW cleanup goals.

![](_page_50_Figure_1.jpeg)

Figure 5-3. Arsenic Concentrations in Baffle Sediment Trap Samples by Site and Period, Compared to LDW Cleanup Goals

### 5.4 Polycyclic Aromatic Hydrocarbons

PAHs were infrequently detected in sediment trap samples (Table 5-5). HPAHs, when detected, were most frequently observed in the three most downstream sites (Mill and Springbrook creeks, and Green River–Foster Links). PAHs were only detected in one sample from Newaukum Creek.

### Table 5-5.Frequency of detection for LPAHs and HPAHs in baffle sediment trap samples by<br/>site.

РАН	Green River – Flaming Geyser	Newaukum Creek	Soos Creek	Mill Creek	Spring -brook Creek	Green River– Foster Links	Total FOD
LPAHs							
Acenaphthene	0/5	0/5	0/5	0/5	0/2	0/4	0/26
Acenaphthylene	0/5	0/5	0/5	0/5	0/2	0/4	0/26
Anthracene	0/5	0/5	1/5	0/5	0/2	0/4	1/26
Fluorene	0/5	0/5	0/5	0/5	0/2	0/4	0/26
Naphthalene	0/5	0/5	0/5	0/5	0/2	0/4	0/26
Phenanthrene	4/5	0/5	2/5	4/5	1/2	3/4	14/26
Total LPAH FOD	13%	0%	10%	13%	8%	13%	10%

РАН	Green River – Flaming Geyser	Newaukum Creek	Soos Creek	Mill Creek	Spring -brook Creek	Green River– Foster Links	Total FOD
HPAHs							
Benzo(a)anthracene	1/5	0/5	2/5	5/5	1/2	2/4	11/26
Benzo(a)pyrene	0/5	0/5	1/5	4/5	2/2	2/4	9/26
Benzo(b,j,k)fluoranthene	1/5	0/5	3/5	5/5	2/2	4/4	15/26
Benzo(g,h,i)perylene	0/5	0/5	0/5	4/5	2/2	2/4	8/26
Chrysene	1/5	0/5	2/5	5/5	2/2	3/4	13/26
Dibenzo(a,h)anthracene	0/5	0/5	0/5	1/5	0/2	0/4	1/26
Fluoranthene	1/5	1/5	3/5	5/5	2/2	4/4	16/26
Indeno(1,2,3-Cd)pyrene	0/5	0/5	0/5	5/5	2/2	2/4	9/26
Pyrene	0/5	1/5	3/5	5/5	2/2	4/4	15/26
Total HPAH FOD	9%	4%	31%	87%	83%	64%	41%
FOD – frequency of detec	tion						

Results for anthracene and phenanthrene, the only LPAHs detected in baffle trap samples, are presented in Table 5-6. In most cases these LPAHs were below the RDL. The highest phenanthrene concentration was detected in Springbrook Creek. Results for all individual HPAHs and total HPAHs are presented in Table 5-7. The highest concentrations were always observed in Springbrook Creek.

Table 5-6.	Summary of phenanthrene and anthracene in baffle traps by site and sampling
	period (µg/kg dw).

LPAH	Period	Green River – Flaming Geyser	Newaukum Creek	Soos Creek	Mill Creek	Springbrook Creek	Green River– Foster Links
	1	8.3 U	8.3 U	7.0 U	14 U	NC	NA
	2	9.6 U	6.6 U	7.3 U	14 U	NC	8.7 U
Anthracene	3	9.9 U	6.3 U	7.5 U	16 U	NC	17 U
	4	14 U	6.2 U	8.8 U	19 U	79 U	7.7 U
	5	6.7 U	6.4 U	14 J	6.2 U	12 U	6.0 U
	Mean	9.7 U	6.8 U	8.9 J	14 U	45 U	9.7 U
	1	14 J	8.3 U	7.0 U	22 J	NC	NA
	2	9.6 U	6.6 U	7.3 U	14 U	NC	8.7 U
Phenanthrene	3	16 J	6.3 U	7.5 U	30 J	NC	64.4
	4	20 J	6.2 U	12 J	25 J	222	12 J
	5	18.9	6.4 U	38.9	29.3	152	26.5
	Mean	16 J	6.7 U	14.5 J	24 J	187	27.8 J
U – non-detect	value; NC	c – sample not o	collected; NA –	sample n	ot analyz	ed; J – estimated	value

$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	НРАН	Period	Green River – Flaming Geyser	Newaukum Creek	Soos Creek	Mill Creek	Springbrook Creek	Green River– Foster Links
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		1	8.3 U	8.3 U	7.0 U	23 J	NC	NA
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$		2	9.6 U	6.6 U	7.3 U	30.2	NC	8.7 U
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	Benzo(a)anthracene	3	9.9 U	6.3 U	7.5 U	33 J	NC	61.9
Mean         10 J         6.8 U         14 J         31 J         172 J         27 J           1         8.3 U         8.3 U         7.0 U         27 J         NC         NA           2         9.6 U         6.6 U         7.3 U         43.0         NC         8.7 U           3         9.9 U         6.3 U         7.5 U         16 U         NC         71.3           4         14 U         6.2 U         8.8 U         35 J         440         7.7 U           5         35 U         33 U         39 J         62 J         474         41.7           6         15 U         12 U         14 J         37 J         457         32 J           8enzo(b,j,k)fluoranthene         1         8.3 U         8.3 U         7.0 U         82.5         NC         NA           2         9.6 U         6.6 U         7.3 U         128         NC         16 J           2         9.6 U         6.6 U         7.3 U         128         NC         175           4         14 U         6.2 U         24.6         86.3         1,220         21.4           5         35 U         33 U         113         164 <td< td=""><td></td><td>4</td><td>14 U</td><td>6.2 U</td><td>12 J 34 0</td><td>31 J 35 6</td><td>79 U 265</td><td>7.7 U 30 0</td></td<>		4	14 U	6.2 U	12 J 34 0	31 J 35 6	79 U 265	7.7 U 30 0
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$		Mean	10 J	6.4 U	14 J	33.0 31 J	172 J	27 J
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		4	0.011	0.011	7011	07.1	NO	NIA
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		1	8.3 U 0.6 U	8.3 U 6 6 U	7.00	27 J 43 0		NA 8711
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	Benzo(a)pyrene	23	9.00	631	7.50	43.0 16 H	NC	0.7 U 71 3
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	Delize(a)pyrelie	4	14 U	6.2 U	8.8 U	35 J	440	7.7 U
$\begin{tabular}{ c c c c c c c c c c c c c c c c c c c$		5	35 U	33 U	39 J	62 J	474	41.7
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		Mean	15 U	12 U	14 J	37 J	457	32 J
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		1	8311	8311	7011	82.5	NC	ΝΔ
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		2	9.6 U	6.6 U	7.3 U	128	NC	16 J
4       14 U       6.2 U       24.6       86.3       1,220       21.4         5       35 U       33 U       113       164       1590       123         Mean       16 J       12 U       32.2 J       112       1,410       84.1 J         1       8.3 U       8.3 U       7.0 U       19 J       NC       NA         2       9.6 U       6.6 U       7.3 U       34.6       NC       8.7 U         Benzo(g,h,i)perylene       3       9.9 U       6.3 U       7.5 U       18 J       NC       31 J         4       14 U       6.2 U       8.8 U       41.2       493       7.7 U         5       35 U       33 U       39 U       32 U       220       15.5         Mean       15 U       12 U       14 U       29 J       356       16 J         1       8.3 U       8.3 U       7.0 U       43.5       NC       NA         2       9.6 U       6.6 U       7.3 U       52.6       NC       8.7 U	Benzo(b,j,k)fluoranthene	3	14 J	6.3 U	9.1 J	100	NC	175
5         35 U         33 U         113         164         1590         123           Mean         16 J         12 U         32.2 J         112         1,410         84.1 J           1         8.3 U         7.0 U         19 J         NC         NA           2         9.6 U         6.6 U         7.3 U         34.6         NC         8.7 U           Benzo(g,h,i)perylene         3         9.9 U         6.3 U         7.5 U         18 J         NC         31 J           4         14 U         6.2 U         8.8 U         41.2         493         7.7 U           5         35 U         33 U         39 U         32 U         220         15.5           Mean         15 U         12 U         14 U         29 J         356         16 J           1         8.3 U         8.3 U         7.0 U         43.5         NC         NA           2         9.6 U         6.6 U         7.3 U         52.6         NC         8.7 U		4	14 U	6.2 U	24.6	86.3	1,220	21.4
Mean         16 J         12 U         32.2 J         112         1,410         84.1 J           1         8.3 U         8.3 U         7.0 U         19 J         NC         NA           2         9.6 U         6.6 U         7.3 U         34.6         NC         8.7 U           Benzo(g,h,i)perylene         3         9.9 U         6.3 U         7.5 U         18 J         NC         31 J           4         14 U         6.2 U         8.8 U         41.2         493         7.7 U           5         35 U         33 U         39 U         32 U         220         15.5           Mean         15 U         12 U         14 U         29 J         356         16 J           1         8.3 U         8.3 U         7.0 U         43.5         NC         NA           2         9.6 U         6.6 U         7.3 U         52.6         NC         8.7 U		5	35 U	33 U	113	164	1590	123
1         8.3 U         8.3 U         7.0 U         19 J         NC         NA           2         9.6 U         6.6 U         7.3 U         34.6         NC         8.7 U           Benzo(g,h,i)perylene         3         9.9 U         6.3 U         7.5 U         18 J         NC         31 J           4         14 U         6.2 U         8.8 U         41.2         493         7.7 U           5         35 U         33 U         39 U         32 U         220         15.5           Mean         15 U         12 U         14 U         29 J         356         16 J           1         8.3 U         8.3 U         7.0 U         43.5         NC         NA           2         9.6 U         6.6 U         7.3 U         52.6         NC         8.7 U		Mean	16 J	12 U	32.2 J	112	1,410	84.1 J
2       9.6 U       6.6 U       7.3 U       34.6       NC       8.7 U         Benzo(g,h,i)perylene       3       9.9 U       6.3 U       7.5 U       18 J       NC       31 J         4       14 U       6.2 U       8.8 U       41.2       493       7.7 U         5       35 U       33 U       39 U       32 U       220       15.5         Mean       15 U       12 U       14 U       29 J       356       16 J         1       8.3 U       8.3 U       7.0 U       43.5       NC       87 U		1	8.3 U	8.3 U	7.0 U	19 J	NC	NA
Benzo(g,h,i)perylene         3         9.9 U         6.3 U         7.5 U         18 J         NC         31 J           4         14 U         6.2 U         8.8 U         41.2         493         7.7 U           5         35 U         33 U         39 U         32 U         220         15.5           Mean         15 U         12 U         14 U         29 J         356         16 J           1         8.3 U         8.3 U         7.0 U         43.5         NC         NA           2         9.6 U         6.6 U         7.3 U         52.6         NC         8.7 U		2	9.6 U	6.6 U	7.3 U	34.6	NC	8.7 U
4         14 U         6.2 U         8.8 U         41.2         493         7.7 U           5         35 U         33 U         39 U         32 U         220         15.5           Mean         15 U         12 U         14 U         29 J         356         16 J           1         8.3 U         7.0 U         43.5         NC         NA           2         96 U         66 U         7.3 U         52 6         NC         8.7 U	Benzo(g,h,i)perylene	3	9.9 U	6.3 U	7.5 U	18 J	NC	31 J
5         35 U         33 U         39 U         32 U         220         15.5           Mean         15 U         12 U         14 U         29 J         356         16 J           1         8.3 U         8.3 U         7.0 U         43.5         NC         NA           2         96 U         66 U         7.3 U         52.6         NC         8.7 U		4	14 U	6.2 U	8.8 U	41.2	493	7.7 U
Mean         15 U         12 U         14 U         29 J         356         16 J           1         8.3 U         8.3 U         7.0 U         43.5         NC         NA           2         96 U         66 U         7.3 U         52.6         NC         8.7 U		5	35 U	33 U	39 U	32 U	220	15.5
1 8.3 U 8.3 U 7.0 U 43.5 NC NA 2 96 U 66 U 73 U 52 6 NC 87 U		Mean	15 U	12 U	14 U	29 J	356	16 J
2 9611 6611 7311 526 NC 8711		1	8.3 U	8.3 U	7.0 U	43.5	NC	NA
		2	9.6 U	6.6 U	7.3 U	52.6	NC	8.7 U
Chrysene         3         9.9 U         6.3 U         7.5 U         56.3         NC         113	Chrysene	3	9.9 U	6.3 U	7.5 U	56.3	NC	113
4 14 0 6.2 0 15 J 42.3 641 11 J		4	14 U	6.2 U	15 J	42.3	641	11 J
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		5 Mean	11 J 11 J	6.4 U	74.9 22.1	65.9 52 1	449 <b>545</b>	53.8 46.5 J
inicali 115 0.00 225 52.1 545 40.55		Mean	113	0.0 0	22 5	52.1	545	40.5 5
1 8.3 U 8.3 U 7.0 U 48.9 NC NA		1	8.3 U	8.3 U	7.0 U	48.9	NC	NA
2 9.6 U 6.6 U 7.3 U 63.5 NC 10 J		2	9.6 U	6.6 U	7.3 U	63.5	NC	10 J
Fluoranthene         3         9.9 U         6.3 U         13 J         69.6         NC         161	Fluoranthene	3	9.9 U	6.3 U	13 J	69.6	NC	161
4 14 U 6.2 U 31.6 60.9 741 20.1		4	14 U	6.2 U	31.6	60.9	/41 500	20.1
5 9.3 J 8.4 J 106 80.5 568 66.6		5 Moon	9.3 J	8.4 J	106	80.5	568	613 I
Weall 10.5 7.1.5 55.1.5 04.7 054 04.5.5		WEall	10.5	/.I J	JJ. I J	04.7	034	0 <del>4</del> .3 J
1 8.3 U 8.3 U 7.0 U 19 J NC NA		1	8.3 U	8.3 U	7.0 U	19 J	NC	NA
2 9.6 U 6.6 U 7.3 U 34.6 NC 8.7 U		2	9.6 U	6.6 U	7.3 U	34.6	NC	8.7 U
Indeno(1,2,3-Cd)Pyrene 3 9.9 U 6.3 U 7.5 U 30 J NC 44.4	Indeno(1,2,3-Cd)Pyrene	3	9.9 U	6.3 U	7.5 U	30 J	NC	44.4
		4	14 U 25 U	6.2 U	8.8 U	44.0	542	1.7 U
Mean 15 U 12 U 14 U 33.8 J 401 20 I 19.9		о Mean	15 U	33 U 12 U	39 U 14 U	33.8 J	200 <b>401</b>	19.9 20.J

#### Table 5-7. Summary of HPAHs in baffle traps by site and sampling period (µg/kg dw).

НРАН	Period	Green River – Flaming Geyser	Newaukum Creek	Soos Creek	Mill Creek	Springbrook Creek	Green River– Foster Links			
Pyrene	1	8.3 U	8.3 U	7.0 U	48.1	NC	NA			
	2	9.6 U	6.6 U	7.3 U	79.4	NC	11 J			
	3	9.9 U	6.3 U	12 J	79.8	NC	159			
	4	14 U	6.2 U	30.4	65.8	810	19			
	5	6.7 U	10 J	115	107	965	83.2			
	Mean	9.7 U	7.5 J	34.3 J	76.0	888	68.2 J			
	1	8.3 U	8.3 U	7.0 U	311 J	NC	NA			
	2	9.6 U	6.6 U	7.3 U	466 J	NC	37 J			
Total HPAHs	3	14 J	6.3 U	34 J	387 J	NC	817J			
	4	14 U	6.2 U	114 J	407 J	4,887 J	72 J			
	5	30 J	18 J	482 J	556 J	4791 J	434			
	Mean	15 J	9.1 J	128.8 J	425.2	J 4,840 J	340 J			
Only HPAHs with at least one detect are included in the table. Means include non-detects at MDL Value U – non-detect value; J – estimated value; NC – sample not collected; NA – sample not analyzed										

All sediment trap PAH concentrations were below the LDW point-based benthic cleanup goals. Phenanthrene and total HPAH results are shown, by location followed by the sample periods in Figures 5-4 and 5-5, respectively. Comparisons to the benthic cleanup goals, which are organic carbon normalized values, are not presented in the figures because only dry weight values are illustrated.

![](_page_53_Figure_3.jpeg)

Figure 5-4. Phenanthrene Concentrations in Baffle Sediment Trap Samples by Site and Period

![](_page_54_Figure_1.jpeg)

Figure 5-5. Total HPAH Concentrations in Baffle Sediment Trap Samples by Site and Period

There are three LDW human health cleanup goals for cPAHs; site-wide is 380 µg TEQ/kg clamming areas is 150 µg TEQ/kg and for beach play areas is 90 µg TEQ/kg. The cPAH TEQs for Springbrook Creek samples were above all three LDW human health cleanup goals (Figure 5-6). In addition, the cPAH TEQs at Mill Creek and Green River–Foster Links during periods 3 and 5, respectively, exceeded the beach play area cleanup goal. No other trap results were greater than the cPAH LDW human health cleanup goals (Figure 5-6).

![](_page_55_Figure_1.jpeg)

Figure 5-6. Total cPAH TEQ in Baffle Sediment Trap Samples by Site and Period, Compared to the LDW Human Health Cleanup Goals

### 5.5 Other Semi-Volatile Compounds

With the exception of one Green River–Foster Links sample, all baffle sediment trap samples were analyzed for 21 additional SVOCs. Approximately 10% of the compounds were detected and are ranked by frequency of detection (FOD) in Table 5-8. Bis(2-ethylhexyl)phthalate was the most frequently detected compound within this group, and was detected at least once at each of three most upstream locations and 100% FOD at the three most downstream locations (Mill and Springbrook creeks, and Green River–Foster Links). The two highest concentrations of bis(2-ethylhexyl)phthalate were found at Springbrook Creek and also exceeded the LDW point-based benthic cleanup goal.

Minimum Movimum Moon										
Other SVOCs	FOD	Detected	Detected	Detected						
		Deteoted	Dettotted	Deleolea						
Bis(2-Ethylhexyl)Phthalate	19/26	19 J	3,900	529 J						
Benzoic Acid	12/26	184	8,560	1,320						
Benzvl Butvl Phthalate	9/26	29.8	186	97.0						
Dimethyl Phthalate	5/26	33.1	55.4	45.9						
Benzyl Alcohol	3/26	19.6	68.8	50.9						
Di-N-Butyl Phthalate	2/26	14 J	17 J	15 J						
Single Detection										
1,2,4-Trichlorobenzene	1/26	1.7 J								
3-,4-Methylphenol	1/26	1,510								
Carbazole	1/17	18 J								
Diethyl Phthalate	1/26	16 J								
Hexachlorobenzene	1/26	3.03								
Phenol	1/26	275								
		Non-detects								
1,2-Dichlorobenzene	0/26									
1,4-Dichlorobenzene	0/26									
2,4-Dimethylphenol	0/26									
2-Methylphenol	0/26									
Dibenzofuran	0/26									
Di-N-Octyl Phthalate	0/26									
Hexachlorobutadiene	0/26									
N-Nitrosodiphenylamine	0/26									
Pentachlorophenol	0/26									
FOD – frequency of detection	i; J – estima	ted value								

## Table 5-8.Summary of other baffle trap SVOCs ranked based on frequency of detection<br/>(μg/kg dw).

### 5.6 PCBs

PCBs in baffle sediment trap samples collected during the first two deployment periods were analyzed as Aroclors; however, none were detected. To improve the potential for PCB detection, samples from the remaining trap deployment periods were analyzed for PCB congeners, as well as archived samples for the two Green River locations from the first two trap deployment periods. Table 5-9 present PCB concentration by location and period. Results for all 209 congeners are presented in Appendix D.

Period	Green River – Flaming Geyser	Newaukum Creek	Soos Creek	Mill Creek	Springbrook Creek	Green River Foster Links			
1	0.361 J	4U a	4U a	4U a	NC	1.03 J			
2	0.140 J	4U ª	4U a	4U ª	NC	0.700 J			
3	0.203 J	0.0162 J	0.524 J	8.22 J	NC	12.0 J			
4	0.549 J	0.0312 J	1.10 J	6.87 J	38.8 J	1.12 J			
5	0.560 J	0.580 J	7.39 J	7.40 J	49.9 J	11.5 J			
Mean	<b>0.363</b> J	<b>0.209</b> J	<b>3.00</b> J	<b>7.50</b> J	<b>44.4</b> J	<b>5.27</b> J			
Note: means	s only include detection	ons							
<sup>a</sup> Results based on total Aroclors									
U – non-dete	ect; J – estimated val	ue; NC – samp	ole not colle	cted					

Table 5-9.	Summary of total PCB results in baffle traps by site and sampling period
	(μg/kg dw).

Total PCB concentrations (as congeners) ranged from 0.0162 to 49.9  $\mu$ g/kg dw. Concentrations in all samples from Springbrook and Mill creeks, as well as those collected during Period 5 at Soos Creek and Periods 3 and 5 at Green River–Foster Links, were greater than the lowest site-wide LDW human health cleanup goal (2  $\mu$ g/kg) (Figure 5-7). All PCB concentrations were below the next lowest LDW human health cleanup goal (500  $\mu$ g/kg for clamming areas) as well as the LDW cleanup goal protective of wildlife (128  $\mu$ g/kg). All total PCB concentrations were below the LDW point-based benthic cleanup goal (12 mg/kg OC or the dw equivalent of 130  $\mu$ g/kg dw).

![](_page_58_Figure_1.jpeg)

Figure 5-7. Total PCB Concentrations in Baffle Sediment Trap Samples by Site and Period, Compared to the LDW Human Health Cleanup Goal

The PCB congener results are also summarized as homolog groups, by location and period (Figure 5-8). With the exception of one sample (Green River – Flaming Geyser, Period 5), PCB concentrations were primarily comprised of congeners in the penta- and hexa-homolog groups, followed by the tetra- and hepta-homolog groups. Homolog patterns at Soos Creek were the least variable. Some slight pattern differences were observed at Mill Creek in Period 4 (wet season) and at Green River-Foster Links in Period 5 (dry season). The most notable pattern differences were observed at Green River – Flaming Geyser in Period 5 where di- and tri-homologs made up a larger percentage of the total relative to other samples. However, the total PCB concentrations were low (0.56  $\mu$ g/kg dw), and therefore, concentrations of these congeners were very low. This trap had been tampered with during the deployment period. In July the trap was found partially pulled out of the water with the inlet out of the water; the trap was moved back into the river further from bank for the remaining deployment period (see Section 2.4). This could result in some uncertainty around these data.

![](_page_59_Figure_1.jpeg)

Figure 5-8. PCB Homolog Patterns in Baffle Sediment Trap Samples by Site and Period

### 5.7 Dioxin/Furan Congeners

Dioxin/furans were analyzed at all locations, except Springbrook Creek, for the first two deployment periods per the study SAP. Dioxin/furans were also analyzed in Period 5 for all locations and at Springbrook Creek during Period 4. Dioxin/furan concentrations ranged from 0.0214 to 4.12  $\mu$ g/kg dw (Table 5-10). The highest concentration was found at Springbrook Creek, followed by Mill Creek. Results for all 17 dioxin/furan congeners are presented in Appendix D.

Period	Green River - Flaming Geyser	Newaukum Creek	Soos Creek	Mill Creek	Springbrook Creek	Green River - Foster Links				
	0.0440.1		0.004.4		NO	0.400.1				
1	0.0443 J	0.0465 J	0.0214 J	1.05 J	NC	0.129 J				
2	0.0248 J	0.0283 J	0.0448 J	1.44 J	NC	0.0815 J				
3	NA	NA	NA	NA	NC	NA				
4	NA	NA	NA	NA	3.49 J	NA				
5	0.0711 J	0.381 J	1.16 J	2.75 J	4.12 J	0.910 J				
Mean	<b>0.0467</b> J	<b>0.152</b> J	<b>0.408</b> J	<b>1.75</b> J	<b>3.81</b> J	<b>0.373</b> J				
J – estimate	J – estimated value; NC – sample not collected; NA – sample not analyzed									

Table 5-10.Summary of total dioxin/furans in baffle traps by site and sampling period<br/>(μg/kg dw).

The highest total dioxin TEQs were also observed in Springbrook Creek followed by Mill Creek (Table 5-11). All total dioxin TEQs for samples from Mill and Springbrook creeks, as

well as the Period 5 samples from Green River-Foster Links, Soos and Newaukum creeks exceeded the lowest site-wide LDW human health cleanup goal (2 ng TEQ/kg). Total dioxin TEQs for all samples, except those from Springbrook Creek, were below the next lowest LDW human health cleanup goal (13 ng TEQ/kg for clamming areas). Total dioxin TEQs in samples from all other locations and periods were below LDW human health cleanup goals. Figure 5-9 groups the total dioxin TEQ results by location, followed by the sample periods, as well as compares results to the site-wide LDW human health cleanup goal of 2 ng TEQ/kg.

	0,					
Period	Green River - Flaming Geyser	Newaukum Creek	Soos Creek	Mill Creek	Springbrook Creek	Green River - Foster Links
1	0.437 J	0.388 J	0.218 J	3.55 J	NC	0.850 J
2	0.563 J	0.261 J	0.426 J	5.05 J	NC	0.516 J
3	NA	NA	NA	NA	NC	NA
4	NA	NA	NA	NA	16.6 J	NA
5	1.51 J	2.19 J	5.53 J	8.94 J	16.6 J	4.39 J
Mean	<b>0.837</b> J	<b>0.945</b> J	<b>2.06</b> J	<b>5.85</b> J	<b>16.6</b> J	<b>1.92</b> J
J – estimate	ed value; NC – samp	le not collected	l; NA – sam	ple not analy	yzed	

Table 5-11.Summary of total dioxin TEQs in baffle traps by site and sampling period (ng<br/>TEQ/kg dw).

![](_page_60_Figure_4.jpeg)

Figure 5-9. Total Dioxin TEQs in Baffle Sediment Trap Samples by Site and Period, Compared to the LDW Human Health Cleanup Goals

### 5.8 Chemistry Data Validation

Data generated by KCEL (conventional parameters, metals, mercury, PAHs, other semivolatile organics, chlorinated pesticides, and PCBs as Aroclors) were validated by King County using EPA National Functional Guidelines for Superfund data (EPA 2008 and 2010b) and the study SAP (King County 2013c). Details of this validation are described in a data validation technical memorandum (Appendix G, Part 1). Validation of PCB and dioxin/furan congener data was completed by Laboratory Data Consultants, Inc. (LDC) in accordance with EPA Region 10 guidance (EPA 1995 and 1996). PCB congener validation reports are provided in Appendix G, Part 2. This section summarizes the major findings of the chemistry data validation for both baffle and jar sediment trap samples.

#### 5.8.1 KCEL Data

The KCEL reviewed all data by comparing results to reference methods and study SAP requirements, and then flagging data with laboratory qualifiers where appropriate. Validation of these data was conducted by Water and Land Resources Division Science Section personnel. The validation process included review of the data anomaly forms, batch reports and analytical quality control (QC) reports downloaded from the KCEL Information Management System (LIMS) database. The following QC parameters were also reviewed: holding time, method blanks, spike blanks and duplicates, matrix spikes and duplicates, laboratory duplicates and surrogates.

Most QC specifications were met and, therefore, many analytes did not require qualifiers. However, some analytes were qualified with a "J", indicating an estimated value. All analytical data are of acceptable quality based on the data validation findings. Results flagged by the laboratory as <MDL were qualified with "U" flags and considered non-detect, whereas results flagged as <RDL were qualified with "J" flags and considered estimated with unknown bias, unless other QC issues were observed. Issues that resulted in the qualification of data are summarized below.

All PSD parameters in three samples were "J" flagged and considered estimated with an unknown bias, because the sums of all phi sizes were outside the 80 to 110% QC limits. Hydrometer data are susceptible to bias in situations where the sample specific gravity differs from the expected value typically used for the PSD calculation or the first time interval (30 seconds) is too large or small, which can cause uncertainty in the phi size captured during this interval and in turn, the sum. Additionally, there were no associated QC samples for eight PSD sample results; therefore, all PSD parameters were qualified with a "J" flag and considered estimated with an unknown bias. The laboratory triplicate results for clay particle size in a different sample were outside QC limits; therefore, all associated clay particle size results were qualified with "J" flags and considered estimated with unknown bias.

Seven samples were analyzed for mercury past the 28-day holding time. Mercury was detected in all samples, and the results were qualified with "J" flags and considered estimated with low bias, as prescribed in the National Functional Guidelines (EPA 2008).

In one sample workgroup, spike blank recoveries for two SVOCs were below the specified QC limits. These compounds were not detected in all six associated samples; therefore, all were qualified with "UJ" flags and considered estimated non-detects with low bias. In another workgroup, matrix spike and matrix spike duplicate recoveries for one semi-volatile organic compound was below the specified QC limits. This compound was not detected in all seven associated samples; therefore, all were qualified with "UJ" flags and considered estimated non-detects with low bias. In another sample, the benzoic acid result was qualified with a "J" flag and considered estimated with unknown bias due to laboratory duplicate results that were outside QC limits.

All chlorinated pesticide results were qualified with "J" flags and considered estimated with unknown bias due to deviations in sample handling and insufficient QC samples. All other KCEL data were used as reported, without qualification.

#### 5.8.2 PCBs and Dioxin/Furans

PCB and dioxin/furan data were validated to Level III by LDC, Inc. Level III validation includes verification of custody, holding times, reporting limits, sample QC and QC acceptance criteria, frequency of QC samples, instrument performance checks, along with initial and routine calibration checks.

#### PCBs

Holding times and instrument performance checks were all within method criteria except as noted below. Recovery could not be quantified for internal standards in the method blank for PCBs-001 and -003 because of lock mass interferences and therefore all 5 samples in the batch were flagged I (detects) or UI (non-detects). This lock mass interference also prevented the quantification of PCBs-001, -002, and -003 in the same method blank and thus all detects in the 5 samples in this batch were J flagged. Samples L63466-1 and -3 failed the initial OC for surrogate recovery for select congeners. There was sufficient sample to re-run L63466-1. The validator rejected (R flagged) the congeners in the primary sample that failed QC limits and rejected congeners in the sample re-run that were acceptable from the primary sample resulting in a full set of congener results for the sample based on the primary and re-run samples. For sample L63466-3 that did not have sufficient sample mass to be re-run, non-detect results for PCBs-001, -002 and -003 were rejected because these congeners failed QC limits. In addition, all detects in re-run sample L63466-1 were J flagged because no on-going precision and recovery (OPR) sample results were available. Eight samples with detected concentrations of PCB-005/008 were J flagged due to high percent recoveries of OPR. Finally, 4 samples with high or low internal standard recoveries resulted in select congeners being flagged [ (detects) or UI (non-detect).

The lowest detected PCB method blank contaminant was PCB-27 (0.2 ng/kg) for work group PRL008.The highest detected PCB congener in method blanks was PCB-20 (1.56 ng/kg) in workgroup WG45262. Total PCBs detected in method blanks ranged from 2.7 to 9.88 ng/kg. Environmental sample congener detections were qualified as non-detect

whenever congener concentrations were less than five times the method blank concentration for that work group.

The analytical laboratory qualified numerous PCB congeners as "K" (AXYS) or "N" (Pacific Rim), indicating that not all identification and qualification criteria were met for these compounds. The maximum potential concentration is reported for "K" or "N" flagged congeners. These analytes were qualified as non-detects (U qualified) based on EPA Region 10 validation requirements.

#### **Dioxin/Furans**

Holding times and instrument performance for all samples analyzed by Pacific Rim Laboratories fell within method specifications. Holding times and all instrument performance for samples analyzed by AXYS Analytical, were also within method specifications except for all 2,3,7,8-TCDF results on column DB-5, which were rejected; 2,3,7,8-TCDF performed better on the second DB-225 column, and these results were used for 2,3,7,8-TCDF quantitation of all AXYS analyzed samples. Therefore, this performance issue did not result in unusable data for this compound; results from the second column were used. All method blanks were below method performance criteria for these samples.

The analytical laboratory qualified dioxin/furan congeners as "K" (AXYS) or "N" (Pacific Rim), indicating that not all identification and qualification criteria were met for these compounds. The maximum potential concentration was reported for "K" or "N" flagged congeners. These analytes were qualified as non-detects by the validator according to the EPA Region 10 validation requirements. All other analytical acceptance criteria were met.

### 5.9 Equipment Blank

One baffle trap equipment blank sample was analyzed for SVOCs; however, none were detected. No other sample contamination from the equipment is expected for baffle or jar sediment traps. These data are included in Appendix D.

## 6.0. SEDIMENT TRAP DISCUSSION

This section discusses spatial and temporal differences in the baffle sediment trap results for the human health LDW contaminants of concern (arsenic, PAHs, PCBs and dioxin/furans). When evaluating these differences, physical parameters must also be considered. Understanding how physical parameters (i.e., PSD, flow, precipitation) can influence chemical results helps explain variability in the data that may not be directly related to seasonal or spatial factors.

Both metals and organic chemicals are typically more strongly associated with finer particles, and thus, the fines content of a sample can influence chemical concentrations (Horowitz and Elrick 1987; Hedges and Keil1995; Borglin et al. 1996). Similarly, samples with higher TOC may have greater concentrations of PAHs, PCBs and dioxin/furans due to hydrophobic characteristics of these compounds. These two factors can also co-vary.

The influence of flow on data results is less straight forward. Higher velocity flows can carry larger particles, increasing the average particle size within samples (e.g., more sand vs silts/clays), which can potentially contribute to lower chemical concentrations in a sample. Higher flows in the Green River are more influenced by Howard Hansen Dam operations than localized storms and associated stormwater runoff. Alternatively, higher flows in the tributaries are more closely associated with storm events and greater stormwater runoff volumes, which may contribute to higher chemical concentrations in a sample, as more particles are washed off from upland areas. Due to the relatively long deployment of the sediment traps (i.e., two/three months), each sample incorporates a variety of flow conditions, further obscuring the potential influence of flow on sample chemical concentrations. As such, relationships between chemical concentrations and flow were not investigated for sediment trap samples. The following sections present spatial and temporal observations, but each includes a general discussion of the relationship between chemical parameters and percent fines or TOC.

### 6.1 Temporal Observations

The baffle trap samples were collected over three seasons: fall/winter (Periods 1 and 4), spring (Period 2), and summer (Periods 3 and 5). The rainfall and flow conditions experienced between the two summer deployment periods (Periods 3 and 5) are quite different. While intended to represent the dry season, the Period 3 deployment captured a major storm event. The degree to which the storm event influenced the material collected by the trap is unknown; therefore, it is uncertain if the results represent dry season conditions (See Section 2.3). Due to the limited number of samples collected for each season, no statistical comparisons were made; however, relative concentrations between periods were considered at each site for arsenic, phenanthrene, fluoranthene, total cPAHs, fines and TOC. The potential temporal influence on PCB concentrations was only assessed for the Green River main stem locations where PCB congener data were available for all

samples.<sup>14</sup> In addition, dioxin/furans were not analyzed in samples collected during each deployment period and thus were not assessed here. Furthermore, Springbrook Creek data were not included, because samples were only collected during two deployment periods.

For chemicals assessed, concentrations were generally within a factor of two between all sample periods at Green River – Flaming Geyer, Newaukum and Mill creeks and between sample periods 1, 2 and 4 at Soos Creek and Green River–Foster Links. Some of the highest PAH and arsenic concentrations in Soos Creek were observed during Period 5 (summer). A similar pattern was observed in the Green River–Foster Links, where the highest PAH, arsenic and PCB concentrations were also observed during the summer sampling periods (Periods 3 and/or Period 5). Overall, the highest chemical concentrations were almost always observed during the period with highest percent fines and/or TOC at a given site. For many sites, this occurred during Period 5, which had the lowest flows and total precipitation, likely facilitating capture of relatively finer material compared to periods with higher flows.

### 6.2 Spatial Comparisons

This section examines spatial differences in baffle trap data and addresses one of the study questions: What are the general spatial differences of PCBs, PAHs, dioxins/furans and arsenic in the major tributaries and the Green River?

This question was evaluated by exploring differences in results between the upstream and downstream main stem sites, as well as spatial differences between the tributary sites. First, baffle trap results were visually compared between sites for each individual period. Then, permutation tests were used to test differences in mean chemical concentrations between the two Green River main stem sites (See Section 4.3 for details). PAHs were not included in these spatial evaluations due to infrequent detections. Additionally, dioxin/furans were not included in the statistical analysis due to insufficient sample size (n = 3).

There was no consistent pattern for fines, arsenic, or fines-normalized arsenic between the Green River main stem sites (Figure 6-1). While TOC was always higher at the upstream site (Green River – Flaming Geyser), total PCBs, OC-normalized PCBs, and OC-normalized dioxin TEQs were always higher at the downstream site (Green River–Foster Links) (Figure 6-1). There were no statistical differences for these parameters between the main stem sites with the exception of total PCBs after normalizing to TOC. HPAHs were more frequently detected at the downstream site (Green River–Foster Links).

In the tributaries, the highest concentrations of all human health LDW contaminants of concern were detected in Springbrook Creek samples, followed by Mill Creek. Finesnormalizing of arsenic data resulted in Newaukum Creek having the highest concentrations, whereas normalizing total PCBs to TOC did not change the ranking of

<sup>&</sup>lt;sup>14</sup> While PCBs were analyzed in all tributary samples, only non-detect Aroclor results are available for the first two deployment periods; therefore, these data were not temporally evaluated.

relative concentrations (Figure 6-2). Mill Creek had the highest dioxin TEQs only after normalizing to TOC. PAHs were almost never detected at Newaukum Creek, but were most frequently detected at Mill Creek and Springbrook Creek. Average phenanthrene and total cPAH concentrations were between 7 and 67 times higher in Springbrook Creek compared to the other tributaries.

The general spatial pattern observed for tributary chemical concentrations (lowest mean concentrations at Newaukum Creek and highest at Springbrook Creek) is also seen for percent fines (Figure 6-2). Non-parametric correlation analysis with Newaukum, Soos, and Mill Creek results combined indicates that concentrations of arsenic, total PCBs, and total dioxin TEQs were all significantly, positively related to percent fines<sup>15</sup>. This suggests that differences in chemical concentrations between tributary sites may be influenced by percent fines or TOC content. All correlation results are presented in Appendix E.

<sup>&</sup>lt;sup>15</sup> PAHs were not included, because of low frequency of detection at Newaukum and Soos Creeks.

![](_page_67_Figure_1.jpeg)

Figure 6-1. Green River Main Stem Baffle Trap Sediment Sample Results by Period: (a) Percent Fines, (b) TOC, (c) Arsenic, (d) Finesnormalized Arsenic, (e) Total PCBs, (f) OC-normalized PCBs, (g) Total Dioxin TEQs, (h) OC-normalized Dioxin TEQs

![](_page_68_Figure_1.jpeg)

Figure 6-2. Tributary Baffle Trap Sediment Sample Results by Period: (a) Percent Fines, (b) TOC, (c) Arsenic, (d) Fines-normalized Arsenic, (e) Total PCBs, (f) OC-normalized PCBs, (g) Total Dioxin TEQs, (h) OC-normalized Dioxin TEQs

## 7.0. FILTERED SOLIDS RESULTS

This section presents results for the filtered solids baseflow and storm event samples collected from the Green River and four major tributaries. Table 7-1 shows the parameters analyzed in samples at each location. All analytical data as reported by the laboratories are presented in Appendix D. Section 7.1 through 7.6 presents PSD, metals, mercury, PAHs, PCBs and dioxin/furan results. A summary of data validation findings for all PSD and chemistry analyses is included in Section 7.7. As a reference point chemical concentrations were compared to LDW cleanup goals. The cleanup goals apply to bedded sediment in the LDW and suspended solids data do not necessarily represent what settles in the LDW. The LDW Sediment Transport Model estimated that only 50% of the upstream incoming material settles in the LDW and that percentage varies by particle size class (QEA 2008) (see Section 4.2).

Parameter	Gr Riv Flai Ge	een ver – ming yser	Newa Cr	lewaukum Creek Soos Creek Mill Creek Black River/ Springbrook		Soos Creek Mill Creek		River/ gbrook	Green River– Foster Links			
Flow Type	Base	Storm	Base	Storm	Base	Storm	Base	Storm	Base	Storm	Base	Storm
PSD	1	5	1	5	1	5	1	5	2	5	3	9
Metals	1	5	1	5	1	5	1	5	2	4	3	7
Mercury	1	4	1	4	1	5	1	5	2	4	2	7
PAHs	1	4	1	5	1	5	1	5	2	4	2	7
PCB- Aroclors	0	3	0	0	0	3	0	2	0	0	0	4
PCB- Congeners	1	5	1	5	1	2	1	3	2	5	3	9
Dioxin/furans	1	5	1	4	1	5	1	5	2	4	3	7

Table 7-1.	Number of samples analyzed by para	ameter and flow type at each location.
		21

PSD – particle size distribution; TOC – total organic carbon; PAH – polycyclic aromatic hydrocarbons; SVOCs – semi-volatile organic chemicals; PCB – polychlorinated biphenyls

### 7.1 Particle Size Distribution

All filtered solids samples were analyzed by the PSD-LD and PSD-SC methods.<sup>16</sup> PSD results are summarized by three size classes: fines, sand and gravel/sand greater than 500  $\mu$ m (larger sands and gravel) with the fines further delineated by silt and clay fractions. The PSD\_SC analytical method only identifies all material greater than 500  $\mu$ m. The results by phi size can be found in Appendix D.

The fines size fraction, specifically silt, comprised the majority of the volume in all baseflow event samples. Percent fines in storm event samples ranged from 42.8 and 81.4% by volume, with silt consistently contributing the largest percentage within this size category. Particles greater than 500  $\mu$ m contributed the least mass in all storm samples (0.32% to 9.11%). Table 7-2 summarizes PSD results by site and flow condition.

Locator	Parameter	Baseflow		Storm Events					
Locator			ĺ	Min	Max		Mean		Median
Green River– Flaming Geyser	Particles >500 µm <sup>a</sup>	0.97	J	1.68	4.93		3.76	J	4.25 J
	Sand <500 µm	25.6	J	35.4	49.1		42.2	J	41.1
	Fines:	73.4	J	45.9	61.2		54.0	J	55.7 J
	Silt	69.9	J	42.3	54.0		49.0	J	50.6 J
	Clay	3.48	J	3.70	7.25		5.01	J	4.90
	Particles >500 µm <sup>a</sup>	1.36		1.35	6.27		3.80		3.78
Nowoukum	Sand <500 µm	40.3		45.9	53.3		48.0		46.8
Creek	Fines:	58.3		42.8	52.8		48.2		49.5
Oreek	Silt	53.8		38.9	48.6		44.5		45.9
	Clay	4.48		3.06	4.15		3.64		3.56
Soos Creek	Particles >500 µm <sup>a</sup>	1.28	J	1.08	7.04		3.50		2.80
	Sand <500 µm	41.5		41.2	49.9		45.1		44.5
	Fines:	57.2		43.1	57.7		51.4		51.9
	Silt	54.6		40.5	54.0		48.7		49.1
	Clay	2.57		2.30	3.67		2.77		2.60
Mill Creek	Particles >500 µm <sup>a</sup>	0.48		1.09	8.38		2.95		1.83
	Sand <500 µm	10.7		17.5	41.2		32.2		34.5
	Fines:	88.8		57.0	81.4		64.8		63.1
	Silt	75.7		50.1	71.3		57.1		55.1
	Clay	13.1		5.70	10.1		7.74		7.82
Black River/ Springbrook	Particles >500 µm <sup>a</sup>	6.53	J	0.60	J 9.11	J	4.10	J	4.80 J
	Sand <500 µm	6.23	J	11.6	J 28.0	J	19.6	J	18.8 J
	Fines:	87.3	J	64.4	J 81.4	J	75.4	J	79.3 J
Creek	Silt	73.3	J	54.1	J 70.2	J	65.7	J	68.9 J
	Clay	13.9	J	6.45	J 11.2	J	9.72	J	10.3 J

#### Table 7-2. Summary of filter solids PSD results by location and flow condition (% by volume).

 $<sup>^{16}</sup>$  PSD-LD estimates % volume of particles < 500  $\mu m$  while PSD-SC determines % mass >500  $\mu m$ . While combining data with different units incorporates uncertainty in samples with a large amount of organic matter, the overall percentage of particles >500  $\mu m$  in these samples is relatively low. Therefore, there is relatively low uncertainty associated with these data (Section 3.1).

Locator	Parameter	Baseflow	Storm Events					
			Min		Max	Mean	Median	
Green River– Foster Links	Particles >500 µm a	0.22 J	0.32	J	2.39	1.17 J	1.04	
	Sand <500 µm	20.2 J	18.2	J	47.3 J	35.0 J	37.2	
	Fines:	79.2 J	49.2	J	80.2 J	63.2 J	61.4	
	Silt	72.5 J	44.4	J	73.3 J	57.2 J	56.0	
	Clay	6.62 J	4.81	J	7.99	6.05 J	5.40	

One baseflow sample was analyzed at each site, except for Black River/Springbrook Creek (2 samples) and Green River–Foster Links (3 samples). Mean values are presented for these two sites; individual results are included in Figure 7-1.

Five storm event samples analyzed at each location, except Green River-Foster Links (9 samples)

<sup>a</sup> The > 500  $\mu$ size class is measured by % of the total mass.

J – estimated value

Figure 7-1 illustrates PSD results for each sample, organized by location and flow condition. In all samples, either silt or sand less than 500  $\mu$ m made up the largest percent of sample volume. Silt comprised the largest percentage of material in samples from the three most downstream locations (Mill Creek, Black River/Springbrook Creek, and Green River–Foster Links). At most locations, there was a larger percentage of fines in baseflow samples relative to storm event samples.

Figure 7-2 presents the mean particle size in storm event samples at each site. On average, the Black River/Springbrook Creek basin storm event samples had the largest percentage of fines (78%), while Newaukum Creek storm event samples had the smallest (48%). On average, gravel and sand greater than 500  $\mu$ m contributed less than 6% of the total sample volume at each site.




Figure 7-1. Particle Size Distribution in Samples by Location and Sampling Date



Figure 7-2. Mean Particle Distribution in Samples at Each Location during Storm Events

# 7.2 Metals

This section summarizes metals results for the filtered solids samples. Table 7-3 summarizes metal concentrations across location and flow condition. Metals concentrations at each site during storm events were not highly skewed (<30% relative percent difference [RPD] between means and medians), except at Green River–Foster Links for cadmium, lead, and silver, where the mean was biased high by one or two samples.

Amelata	Leaster	Deseflere		Storm	n Events	
Analyte	Locator	Baseflow	Min	Мах	Mean	Median
	Green River–Flaming Geyser	15.0	9.62	14.6	11.1	10.4
	Newaukum Creek	7.28	4.62	9.45	7.59	8.29
Areania	Soos Creek	9.64	6.28	14.9	11.0	11.4
Arsenic	Mill Creek	42.7	15.6	34.6	21.8	19.5
	Black River/Springbrook Creek	47.5	24.1	50.3	35.5	33.9
	Green River–Foster Links	39.9	8.71	24.5	14.2	12.6
	Green River–Flaming Geyser	0.248	0.18	J 0.310	0.21 J	0.188
	Newaukum Creek	0.327	0.141	0.406	0.326	0.377
Codmium	Soos Creek	0.302	0.179	0.469	0.324	0.290
Caumium	Mill Creek	0.391	0.433	0.792	0.594	0.568
	Black River/Springbrook Creek	1.71 J	1.56	8.79	J 4.76 J	4.34
	Green River–Foster Links	0.436	0.173	1.02	J 0.420 J	0.261
	Green River–Flaming Geyser	13.1	18.1	25.0	20.2	19.2
	Newaukum Creek	23.5	21.6	25.4	23.4	23.5
Chromium	Soos Creek	33.8	33.6	41.0	38.1	38.1
Chronnun	Mill Creek	19.5	22.5	28.2	24.9	23.1
	Black River/Springbrook Creek	27.3	30.9	75.5	48.0	42.8
	Green River–Foster Links	26.0	24.6	46.0	31.2	30.0
	Green River–Flaming Geyser	25.5	32.4	47.5	36.8	33.4
	Newaukum Creek	43.3	25.3	49.4	41.9	46.1
Coppor	Soos Creek	24.0	20.8	35.8	28.4	28.5
Copper	Mill Creek	31.8	37.1	57.2	44.3	40.2
	Black River/Springbrook Creek	51.0	77.4	102	87.1	84.6
	Green River–Foster Links	37.1	31.0	91.6	46.9 J	40.1
	Green River–Flaming Geyser	9.25	8.30	13.1	10.1 J	10.2
	Newaukum Creek	13.6	5.84	15.6	12.4	13.6
Lood	Soos Creek	13.7	10.7	22.6	16.1	15.8
Leau	Mill Creek	28.5	29.8	54.1	38.0	31.2
	Black River/Springbrook Creek	36.6	39.3	89.9	62.3	60.0
	Green River–Foster Links	17.6	8.88	70.0	24.2	14.2

#### Table 7-3. Filtered solids metals results summarized by site and flow condition (mg/kg dw).

Angluta	Leaster	Deseflow				Storr	n Ev	vents			
Analyte	Locator	Dasenow		Min		Max		Mear	۱	Media	ın
	Green River–Flaming Geyser	12.0		16.4		22.7		18.4		18.2	
	Newaukum Creek	21.8		21.5		26.4		23.5		23.1	
Niekol	Soos Creek	36.2		39.7		46.2		42.3		41.8	
INICKEI	Mill Creek	14.5		18.9		25.2		21.3		20.5	
	Black River/Springbrook Creek	18.8		20.6		37.4		27.2		25.4	
	Green River–Foster Links	21.8		22.7		39.5		27.4		26.5	
	Green River–Flaming Geyser	0.078	J	0.079	J	0.15	J	0.11	J	0.11	J
	Newaukum Creek	0.10	J	0.048	J	0.10	J	0.084	J	0.092	J
Silver	Soos Creek	0.090	J	0.065	J	0.15	J	0.10	J	0.077	J
Silver	Mill Creek	0.141		0.120		0.271		0.169		0.142	
	Black River/Springbrook Creek	0.19	J	0.19	J	0.56	J	0.35	J	0.354	
	Green River–Foster Links	0.14	J	0.072	J	0.637		0.22	J	0.13	J
	Green River–Flaming Geyser	41.7		50.0		84.8		65.0		63.9	
	Newaukum Creek	48.7		41.6		60.7		53.0		54.5	
Vanadium	Soos Creek	34.9		38.9		48.2		42.4		40.7	
Vanaulum	Mill Creek	59.2		48.8		74.0		57.7		54.2	
	Black River/Springbrook Creek	59.5		55.1		67.7		60.9		60.4	
	Green River–Foster Links	67.9		48.7		75.1		61.7		63.0	
	Green River–Flaming Geyser	93.3		80.6		112		88.5		83.3	
	Newaukum Creek	134		67.9		183		142		159	
Zina	Soos Creek	81.6		66.1		145		117		136	
ZINC	Mill Creek	216		175		278		217		210	
	Black River/Springbrook Creek	453		629		823		700		674	
	Green River–Foster Links	151		78.0		443		173		115	

FOD – 100% for all metals.

One baseflow sample analyzed at each site, except Black River/Springbrook Creek (2 samples) and Green River–Foster Links (3 samples). Average values are presented for these two sites; individual results included in Figure 7-3 for arsenic, and appendices D and F for other metals.

Five storm event samples analyzed at each site, except Black River/Springbrook Creek (4 samples) and Green River–Foster Links (7 samples).

dw – dry weight; J – estimated value

Arsenic concentrations ranged from 4.62 to 59.7<sup>17</sup> mg/kg dw. Arsenic concentrations in only three storm event samples (two from Newaukum Creek and one from Soos Creek) were below the LDW site-wide human health cleanup goal (7 mg/kg dw) Average arsenic storm event concentrations at all locations were greater than this cleanup goal. Arsenic concentrations in one baseflow sample from the Black River/Springbrook Creek basin also exceeded the LDW point-based benthic cleanup goal (57 mg/kg dw). Variability in arsenic

<sup>&</sup>lt;sup>17</sup> This maximum was observed in one of the two baseflow samples at Black River; the table lists the average concentration for two baseflow samples.

concentrations was low for the three most upstream sites, and higher for the three most downstream sites (Figure 7-3).

For the remaining metals, variability within a site was generally lowest at Newaukum Creek and Green River at Flaming Geyser and highest at Green River–Foster Links. Concentrations also varied between samples collected at Black River and Springbrook Creek. Cadmium concentrations in two storm event samples from the Black River/Springbrook Creek basin were above the LDW point-based benthic cleanup goal (5.1 mg/kg). Zinc concentrations in all Black River/Springbrook Creek storm samples and one baseflow sample, were above the LDW point-based benthic cleanup goal (410 mg/kg). All remaining metals concentrations were below cleanup goals. Figures for metals other than arsenic are included as Appendix F.



Figure 7-3. Arsenic Concentrations in Filtered Solis Samples by Location Compared to the LDW Human Health and Benthic Cleanup Goals

## 7.3 Mercury

Mercury was detected in all filtered solids samples at all locations and flow conditions (Table 7-4). Mercury concentrations ranged from 0.049 to 0.226 mg/kg dw and. were below the LDW point-based benthic cleanup goal. A figure illustrating baseflow and storm event mercury concentrations by location is included in Appendix F.

Loostor	Pacafla		Storm Events											
Locator	Dasenow		Min		Max		Mean	1	Median					
Green River–Flaming Geyser	0.12	J	0.10	J	0.180	J	0.14	J	0.13	J				
Newaukum Creek	0.14	J	0.055	J	0.13	J	0.10	J	0.11	J				
Soos Creek	0.10	J	0.054	J	0.16	J	0.11	J	0.10	J				
Mill Creek	0.10	J	0.101	J	0.15	J	0.12	J	0.12	J				
Black River/Springbrook Creek	0.056	J	0.10	J	0.199		0.15	J	0.15	J				
Green River–Foster Links	0.11	J	0.0773		0.226		0.13	J	0.11	J				

<b>T</b> - L L - <b>T</b> - A				
l able 7-4.	Filtered solids mercur	y results summarized b	y site and flow (	condition (mg/kg dw).

FOD = 100%

One baseflow sample analyzed at each site, except Black River/Springbrook Creek and Green River– Foster Links where two baseflow samples were analyzed for mercury. Average values are presented for these two sites; individual results included in appendices D and F.

Four to five storm event samples analyzed at each site, except Green River–Foster Links where seven storm samples were analyzed for mercury.

dw - dry weight; J - estimated value

## 7.4 Polycyclic Aromatic Hydrocarbons

Phenanthrene was detected in all but one of the baseflow samples collected in the Black River/Springbrook Creek basin where no LPAHs were detected. Fluorene and naphthalene were also frequently detected in baseflow samples. In storm event samples, anthracene, naphthalene and phenanthrene were detected in over 80% of the samples, while the FOD for acenaphthene was relatively low (30%). Frequency of detection for all LPAH compounds was highest at Mill Creek (77%) and lowest at Green River – Flaming Geyser (39%). Frequency of detection for LPAHs during storm events is summarized by compound and location in Table 7-5.

Table 7-5.	Frequency of detection for individual L	_PAHs by site during storm events.

LPAH Compound	Green River – Flaming Geyser	Newaukum Creek	Soos Creek	Mill Creek	Black River/ SC <sup>a</sup>	Green River– Foster Links	Total FOD
2-Methylnaphthaleneb	2/4	1/5	0/5	3/5	1/4	5/7	40%
Acenaphthene	0/4	1/5	3/5	2/5	1/4	2/7	30%
Acenaphthylene	0/4	3/5	4/5	4/5	1/4	1/7	43%
Anthracene	1/4	5/5	5/5	5/5	4/4	4/7	80%

LPAH Compound	Green River – Flaming Geyser	Newaukum Creek	Soos Creek	Mill Creek	Black River/ SC <sup>a</sup>	Green River– Foster Links	Total FOD
Fluorene	1/4	4/5	4/5	3/5	1/4	3/7	53%
Naphthalene	3/4	5/5	5/5	5/5	2/4	6/7	87%
Phenanthrene	4/4	5/5	5/5	5/5	4/4	7/7	100%
Total FOD	39%	69%	74%	77%	50%	57%	62%

<sup>a</sup> All LPAHs detected in one Springbrook Creek sample. Only anthracene and phenanthrene were detected at Black River storm event samples.

<sup>b</sup> 2-methylnaphthalene not included in total LPAHs.

SC – Springbrook Creek; FOD – frequency of detection

Total LPAHs ranged from 9.58 to 437  $\mu$ g/kg dw across all sites (Table 7-6). Variability in LPAH concentrations was greatest in storm event samples from Green River–Foster Links (Figure 7-4). Variability was also high between storm event samples collected in Black River and Springbrook Creek. LDW benthic cleanup goals are based on TOC normalized PAH concentrations. Because TOC could not be analyzed in filtered solids samples (see Section 2.2.2), Total LPAH concentrations were compared to the dry weight equivalent concentration of the LDW benthic cleanup goal<sup>18</sup>. All total LPAH concentrations were well below this value (5,200  $\mu$ g/kg).

# Table 7-6.Filtered solids total LPAH results summarized by site and flow condition<br/>(μg/kg dw).

Logotor	Basafle	Storm Events									
Locator	Basenow		Min		Max		Mear	Mean		an	
Green River–Flaming Geyser	29.8	J	16	J	56.0	J	37.0	J	38.0	J	
Newaukum Creek	30.8	J	9.58		61.6	J	41.5	J	46.5	J	
Soos Creek	80.9	J	22.8	J	104	J	73.4	J	76.9	J	
Mill Creek	54.7	J	43.3	J	116	J	75.2	J	71.7	J	
Black River/Springbrook Creek	148	J	210	J	437	J	322	J	321	J	
Green River–Foster Links	30.1	J	20.9	J	319	J	93.2	J	47.5	J	

One baseflow sample analyzed at each site, except Black River/Springbrook Creek and Green River–Foster Links site where two baseflow samples were analyzed; average values presented for these two sites; individual results included in Appendix D.

Five storm event samples analyzed at each site, except Black River/Springbrook Creek (4 samples), Green River – Flaming Geyser (4 samples) and Green River–Foster Links (7 samples).

dw – dry weight; J – estimated value

<sup>&</sup>lt;sup>18</sup> The LDW point-based benthic cleanup goal is equal to the SMS Sediment Quality Standard, which is an organic carbon normalized value. The dry weight equivalent corresponds to the Lowest Apparent Effects Threshold value.



Figure 7-4. Total LPAH Concentrations in Filtered Solids Samples by Location

HPAH compounds were frequently detected (FOD > 90%) during storm events at all sites except Green River–Flaming Geyser, where FOD was only 56% (Table 7-7). In baseflow samples, benzo(a)anthracene, benzo(b,j,k)fluoranthene, chrysene, fluoranthene and pyrene were detected at all sites, while benzo(a)pyrene, benzo(g,h,i)perylene, and indeno(1,2,3-Cd)pyrene were detected at all sites but Green River -Flaming Geyser.

Dibenzo(a,h)anthracene was only detected in baseflow samples at Soos and Mill creeks and one Green River–Foster Links baseflow sample.

HPAH Compound	Green River – Flaming Geyser	Newaukum Creek	Soos Creek	Mill Creek	Black River/ SC	Green River– Foster Links	Total FOD
Benzo(a)anthracene	2/4	5/5	5/5	5/5	4/4	7/7	93%
Benzo(a)pyrene	1/4	5/5	5/5	5/5	4/4	6/7	87%
Benzo(b,j,k)fluoranthene	4/4	5/5	5/5	5/5	4/4	7/7	100%
Benzo(g,h,i)perylene	1/4	5/5	5/5	5/5	4/4	6/7	87%
Chrysene	3/4	5/5	5/5	5/5	4/4	7/7	97%
Dibenzo(a,h)anthracene	1/4	5/5	3/5	5/5	4/4	6/7	73%
Fluoranthene	4/4	5/5	5/5	5/5	4/4	7/7	100%
Indeno(1,2,3-Cd)pyrene	1/4	5/5	4/5	5/5	4/4	6/7	83%
Pyrene	3/4	5/5	5/5	5/5	4/4	7/7	97%
Total FOD	56%	100%	93%	100%	100%	92%	91%
SC – Springbrook Creek;	FOD – frequenc	cy of detection					

 Table 7-7.
 Frequency of detection for individual HPAHs by site during storm events.

Total HPAHs ranged from 23 to 9,420  $\mu$ g/kg dw across all sites (Table 7-8). Variability was greatest in storm event samples at Green River–Foster Links, and lowest at Green River–Flaming Geyser (Figure 7-5). Variability in HPAH concentrations was also high between storm event samples collected at Black River and Springbrook Creek. Total HPAH concentrations were compared to dry weight equivalent concentrations of the LDW point-based benthic cleanup goal (12,000  $\mu$ g/kg)<sup>19</sup>; all values were below this value.

# Table 7-8.Total HPAH filtered solids results summarized by site and flow condition<br/>(μg/kg dw).

Loostor	Baseflow		Storm Events									
Eocator			Min	Min			Mean		Median			
Green River–Flaming Geyser	63.3	J	23	J	91.2	J	63.3	J	69.4	J		
Newaukum Creek	221	J	83.9	J	532	J	291	J	296	J		
Soos Creek	855	J	130		777	J	535	J	596	J		
Mill Creek	723	J	592	J	1,510		1,020	J	984	J		
Black River/Springbrook Creek	2,920	J	4,560	J	9,420	J	6,700	J	6,410	J		
Green River–Foster Links	302	J	108	J	3,890		1,200	J	409	J		

One baseflow sample analyzed at each site, except Black River/Springbrook Creek and Green River– Foster Links site where two baseflow samples were analyzed; average values presented for these two sites; individual results included in Appendix D

Five storm event samples analyzed at each site, except Black River/Springbrook Creek (4 samples), Green River – Flaming Geyser (4 samples) and Green River–Foster Links (7 samples).

dw - dry weight; J - estimated value

<sup>&</sup>lt;sup>19</sup> The LDW point-based benthic cleanup goal is equal to the SMS Sediment Quality Standard, which is an organic carbon normalized value.



Figure 7-5. Total HPAH Concentrations in Filtered Solids Samples by Location

The three LDW human health cleanup goals are based on cPAH TEQs (see Section 4.1). Filtered solids results were above the site-wide LDW human health cleanup goal of 380  $\mu$ g TEQ/kg in all storm event samples, and one baseflow sample, collected in the Black River/Springbrook Creek basin, as well as one storm sample from Green River–Foster Links. Additional samples were above the LDW human health cleanup goals for clamming areas (150  $\mu$ g TEQ/kg), including storm event averages at Mill Creek, the Black River/Springbrook Creek basin, and the Green River–Foster Links site. A few additional samples from Newaukum and Mill creeks, and Green River–Foster Links were greater than the human health cleanup goal for beach play areas (90  $\mu$ g TEQ/kg) (Figure 7-6).



Figure 7-6. Total cPAH TEQs in Filtered Solids Samples by Location Compared to LDW Cleanup Goals

# 7.5 PCBs

PCB Aroclors were analyzed in twelve samples, but were only detected in 4 samples (all detections< RDL). To improve the potential to detect PCBs, the remaining filtered solids samples (collected after April 2013) were analyzed for PCB congeners, as well as seven archived samples collected from the main stem Green River previously analyzed for Aroclors.

Multiple PCB congeners were detected in each sample, resulting in 100% FOD for total PCBs. Total PCB concentrations ranged from 0.611 to 194  $\mu$ g/kg dw and are summarized in Table 7-9 by location and flow condition (results for all congeners are presented in Appendix D). Variability was greatest in storm event samples at Green River–Foster Links, and lowest at Soos Creek (Figure 7-7). Variability was also high between storm event samples collected at Black River and Springbrook Creek. Total PCB concentrations in all but four samples from Green River – Flaming Geyser and one sample from Newaukum Creek were greater the lowest site-wide LDW human health cleanup goal (2  $\mu$ g/kg); mean storm event concentrations at all locations also were above this cleanup goal. Because TOC could not be analyzed in filtered solids samples (see Section 2.2.2), total PCB concentrations were compared to the dry weight equivalent concentration of the LDW point-based benthic cleanup goal.<sup>20</sup> Total PCB concentrations in two samples from the Black River/Springbrook

<sup>&</sup>lt;sup>20</sup> The LDW benthic cleanup goal is equal to the SMS Sediment Quality Standard.

Creek basin were above this value (130  $\mu$ g/kg), however, average storm event concentration at this location did not exceed this value. All other sites had concentrations below the LDW point-based benthic cleanup goal.

Loostor	Basafi	<b>0</b> .W	Storm Events									
Locator	Dasellow		Min		Max		Mean		Median			
Green River–Flaming Geyser	1.48	J	0.611	J	5.92	J	2.93	J	1.90	J		
Newaukum Creek	5.78	J	1.18	J	7.19	J	3.60	J	3.21	J		
Soos Creek	6.83	J	5.18	J	5.87	J	5.53	J	5.53	J		
Mill Creek	10.2	J	10.2	J	15.0	J	12.5	J	12.4	J		
Black River/Springbrook Creek	38.1	J	43.4	J	194	J	116	J	127	J		
Green River–Foster Links	7.75	J	2.20	J	99.9	J	29.9	J	8.83	J		

#### Table 7-9. Total PCB filtered solids results summarized by site and flow condition (µg/kg dw).

One baseflow sample analyzed at each site, except Black River/Springbrook Creek (2 samples) and Green River–Foster Links (3 samples); average values for these two sites presented, individual results included in Appendix D. All results based on PCB congener analysis.

Five storm event samples analyzed at each location, except Soos Creek (2), Mill Creek (3) and Green River–Foster Links (9 samples). All results based on PCB congener analysis.

PCB Aroclors were detected in 3 storm event samples not analyzed for PCB congeners at Soos Creek (14.2  $\mu$ g/kg dw) and Mill Creek (12.3 and 16.8  $\mu$ g/kg dw). All detections were < RDL.

dw - dry weight; J - estimated value

The PCB congener results are also summarized as homolog groups, grouped by location and flow condition (Figures 7-8 and 7-9). The penta- and hexa- homolog groups comprised over 40% of the total concentration, while the tetra- and hepta-homolog groups represented about 30%. The homolog patterns across samples from each location were similar, with the exception of a few samples that had more distinct patterns (e.g., Green River – Flaming Geyser on April 4, 2013 and Green River–Foster Links on November 14, 2015).



# Figure 7-7. Total PCB Concentrations in Filtered Solids Samples by Location Compared to the LDW Human Health and Benthic Cleanup Goals



Figure 7-8. PCB Homolog Pattern for Green River Main Stem Filtered Solids Samples



Figure 7-9. PCB Homolog Patterns for Tributary Filtered Solids Samples

■ Mono- ■ Di- ■ Tri- ■ Tetra- ■ Penta- ■ Hexa- ■ Hepta- ■ Octa- ■ Nona- ■ Deca-

## 7.6 Dioxin/Furan Congeners

At least one dioxin/furan congener was detected in all samples, except one from Green River – Flaming Geyser where all congeners were non-detect (U flagged) resulting in overall FOD of 97%. Total dioxin/furan concentrations ranged from a non-detect to  $8.54 \mu g/kg dw$  (Table 7-10). Results for all 17 dioxin/furan congeners are presented in Appendix D.

Table 7-10.	Total dioxin/furan filtered solids results summarized by site and flow condition
	(μg/kg dw).

Loostor	Baseflow		Storm Events							
Locator			Min	Min Max			Mean		Median	
Green River–Flaming Geyser	0.178	J	0.0919	U	0.232	J	0.170	J	0.176	J
Newaukum Creek	1.24	J	0.475	J	2.00	J	1.33	J	1.42	J
Soos Creek	0.890	J	0.415	J	1.63	J	1.05	J	0.880	J
Mill Creek	3.45	J	3.19	J	8.54	J	4.65	J	3.70	J
Black River/Springbrook Creek	2.35	J	3.27	J	6.26	J	5.06	J	5.36	J
Green River–Foster Links	0.794	J	0.284	J	4.61	J	1.55	J	1.12	J

One baseflow sample analyzed at each site, except Black River/Springbrook Creek (2 samples) and Green River–Foster Links (3 samples); average values are presented for these two sites, individual results included in Appendix D.

Five storm event samples analyzed at each location, except Newaukum and Black River/Springbrook creeks (4 each) and Green River–Foster Links (7 samples).

dw - dry weight; J - estimated value; U - non-detect value

Total dioxin TEQs ranged from 0.862 to 27.6 ng TEQ/kg dw (Table 7-11). Variability was greatest in storm event samples at Mill Creek, and Green River–Foster Links and lowest at Green River – Flaming Geyser. Total dioxin TEQ concentrations in all but two samples from Green River – Flaming Geyser, and two samples from Green River–Foster Links, were above the lowest site-wide LDW human health cleanup goal (2 ng TEQ/kg) (Figure 7-10). All storm event samples from the Black River/Springbrook Creek basin, and some storm event samples from Mill Creek and Green River-Foster Links, also exceeded the next lowest LDW human health cleanup goal (13 ng TEQ/kg for clamming areas); only storm event mean concentrations at Mill Creek and the Black River/Springbrook Creek basin were above the goal for clamming areas.

# Table 7-11.Total dioxin TEQs filtered solids results summarized by site and flow condition (ng<br/>TEQ/kg dw).

Loostor	Pacoflow	Storm Events							
Eocator	Basenow	Min	Мах		Mean		Median		
Green River–Flaming Geyser	1.37 J	0.862 、	J 2.93	J 2	2.02	J	2.09	J	
Newaukum Creek	9.97 J	2.55	J 12.0	J 6	5.92	J	6.57	J	
Soos Creek	5.31 J	2.46	J 9.89	J 6	6.08	J	4.87	J	
Mill Creek	11.7 J	12.0	J 27.6	J 1	7.0	J	15.1	J	
Black River/Springbrook Creek	10.2 J	14.0	J 27.5	J 2	21.9	J	23.1	J	
Green River–Foster Links	3.48 J	1.62 、	J 23.4	J 7	<b>'</b> .11	J	4.21	J	

One baseflow sample analyzed at each site, except Black River/Springbrook Creek (2 samples) and Green River–Foster Links (3 samples); average values are presented for these two sites, individual results included in Appendix D.

Five storm event samples analyzed at each location, except Newaukum and Black River/Springbrook creeks (4 each) and Green River–Foster Links (7 samples).

TEQ – toxicity equivalents; dw – dry weight; J – estimated value



Figure 7-10. Total Dioxin TEQs in Filtered Solids Samples by Location Compared to LDW Cleanup Goals

## 7.7 Chemistry Data Validation

Data generated by KCEL (conventional parameters, metals, mercury, PAHs, other SVOCs, chlorinated pesticides, and PCBs as Aroclors) were validated by King County using EPA National Functional Guidelines for Superfund data (EPA 2008 and 2010b) and the study SAP (King County 2013c). Details of this validation are described in a data validation technical memorandum (Appendix G, Part 1). Validation of PCB and dioxin/furan congener data was completed by LDC in accordance with EPA Region 10 guidance (EPA 1995 and 1996). PCB congener validation reports are provided in Appendix G, Part 2. This section summarizes the major findings of the chemistry data validation for filtered solids samples.

#### 7.7.1 KCEL Data

The KCEL reviewed all data by comparing the results to reference methods and SAP requirements, and then flagged data with laboratory qualifiers where appropriate. Validation of these data was conducted by Water and Land Resources Division Science Section personnel. The validation process included review of the data anomaly forms, batch reports and analytical QC reports. The following QC parameters were also reviewed: holding time, method blanks, spike blanks and duplicates, matrix spikes and duplicates, laboratory control samples, standard reference material and duplicates, laboratory replicates, and surrogates.

Most QC specifications were met and, therefore, many analytes did not require qualifiers. However, some analytes were qualified with a "J", indicating an estimated value. All analytical data are of acceptable quality based on the data validation findings. Results flagged by the laboratory as <MDL were qualified with "U" flags and considered non-detect, whereas results flagged as <RDL were qualified with "J" flags and considered estimated with unknown bias, unless other QC issues were observed. Issues that resulted in the qualification of data are summarized below.

Eight samples had no associated QC samples for PSD analysis; therefore, all PSD parameters were qualified with a "J" flag and considered estimated with an unknown bias. Three laboratory duplicate results were outside QC limits, resulting in "J" flags for various particle size results in two samples. During PSD laser diffraction analysis, the predicted distribution is compared to the actual sample distribution and the weighted residual percentage must be within acceptance limits; the PSD laser diffraction results for 11 samples should be qualified with a "J" flag and considered estimates with unknown bias because the measured results were outside the accuracy of the method, due to residuals outside acceptance limits.

The holding time for mercury was exceeded in one sample; the result was qualified with a "J" flag and considered estimated with a low bias. The mercury result in two other samples were qualified with "J" flags and considered estimated with unknown bias due to laboratory duplicate and/or matrix spike and matrix spike duplicate results outside QC limits.

The lead result for one sample was qualified with a "J" flag and considered estimated with unknown bias due to matrix spike and laboratory duplicate results outside QC limits. The copper result in one sample was also qualified with a "J" flag and considered estimated with unknown bias due to laboratory duplicate results outside QC limits. The RPD between the cadmium recoveries in the laboratory control sample and associated laboratory control sample duplicate in one workgroup was outside QC limits, indicating unsatisfactory precision. The cadmium results of the three samples associated with this workgroup were qualified with "J" flags and considered estimated with unknown bias.

In one sample, indeno(1,2,3-Cd)pyrene and benzo(g,h,i)perylene results were qualified with "U" flags and considered non-detects due to method blank results. In another sample, pyrene results were also qualified with "U" flags based on method blank results. The sample results for these compounds were less than the RDL, so the RDL value was considered the level of detection. Individual PAH compounds in multiple samples were qualified for one of the following reasons: matrix spike, matrix spike duplicate, standard reference material, and standard reference material duplicate recoveries outside of QC limits. Samples were qualified with a "J" flag and considered estimated with either low or high bias. Thirteen different PAHs were qualified with "J" flags between 14 samples.

The storage jars for PCB Aroclor analysis from two samples cracked, and an unknown amount of sample was lost. No Aroclors were detected in these samples; therefore results were qualified with "UJ" flags and considered estimated non-detects with unknown bias. Additionally there was matrix interference for Aroclor 1254 in one sample, resulting in a "J" flag with unknown bias.

All chlorinated pesticide results were qualified with "J" flags and considered estimated with unknown bias due to deviations in sample handling and insufficient QC samples. All other KCEL data were used as reported, without qualification.

### 7.7.2 PCBs and Dioxins/Furans

PCB and dioxin/furan data were validated to Level III by LDC, Inc. Level III validation includes verification of custody, holding times, reporting limits, sample QC and QC acceptance criteria, frequency of QC samples, instrument performance checks, along with initial and routine calibration checks.

#### PCBs

Holding times and instrument performance checks were all within method criteria except as noted below. Recovery could not be quantified for internal standards in the method blank for PCBs-001 and -003 because of lock mass interferences and therefore all 7 samples in the batch were flagged J (detects) or UJ (non-detects). This lock mass interference also prevented quantification of PCBs-001, -002, and -003 in the same method blank, and thus all detects in the 7 samples in this batch were J flagged. The laboratory duplicate in this same batch had a RPD greater than the SAP limit of 50% for a number of detected congeners; all affected congeners were J flagged in one sample. PCB-011 in one sample was J flagged because the laboratory duplicate was greater than SAP limit of 50%. Internal standard percent recovery was low for two labeled congeners in one sample resulting in detected concentrations for PCBs-001 and 003 being J flagged and non-detect results for PCB-002 being rejected. Sample L64265-1 failed initial QC for surrogate recovery for select congeners. There was sufficient sample to re-run L64265-1. The validator rejected (R flagged) those congeners in the primary sample that failed QC limits. In addition, the validator rejected congeners in the sample re-run that were acceptable from the primary sample. Both of these actions resulted in a full set of congener results for each sample based on the primary and re-run samples. In addition, all detects in re-run of sample L64265-1 were J flagged because no OPR sample results were available. Five samples with detected concentrations of co-eluting PCB-005/008 were J flagged due to high percent OPR recoveries. Finally, 1 sample had high internal standard recoveries resulting in select congeners being flagged J (detects) or UJ (non-detect).

The lowest detected PCB congener in method blanks was PCB-27 (0.2 ng/kg) for work group RRL008.The highest detected PCB congener in method blanks was PCB-11 (2.04 ng/kg) in workgroup WG46439. Total PCBs detected in method blanks ranged from 2.7 to 15.1 ng/kg. Environmental sample congener detections were qualified as non-detect whenever congener concentrations were less than five times the method blank concentration for that work group.

Numerous PCB congeners were qualified by the analytical laboratory as "K" (AXYS) or "N" (Pacific Rim) indicating not all identification and qualification criteria were met for these compounds. The maximum potential concentration is reported for "K" or "N" flagged congeners. These analytes were qualified as non-detects (U qualified) based on EPA Region 10 validation requirements.

#### **Dioxin/Furans**

Holding times and instrument performance fell within method specifications for all samples analyzed by Pacific Rim Laboratories. For those analyzed by AXYS Analytical, holding times and all instrument performance were also within method specifications except for all 2,3,7,8-TCDF results on column DB-5, which were rejected; 2,3,7,8-TCDF performed better on the second DB-225 column; these results were used for 2,3,7,8-TCDF quantitation of all AXYS analyzed samples. Therefore, this performance issue did not result in unusable data for this compound. All method blanks were below method performance criteria for these samples.

Dioxin/furan congeners were qualified by the analytical laboratory as "K" (AXYS) or "N" (Pacific Rim), indicating not all identification and qualification criteria were met for these compounds. The maximum potential concentration was reported for "K" or "N" flagged congeners. These analytes were qualified as non-detects by the validator according to the EPA Region 10 validation requirements. All other analytical acceptance criteria were met.

## 7.8 Equipment Blank

One filter equipment blank was analyzed for TOC, metals, and SVOCs. TOC was detected at six times the RDL, which was the reason TOC analysis was not included for filtered solids samples. Copper was detected at a concentration less than the RDL, and zinc was detected at a concentration just above the RDL. Concentrations of copper and zinc in the environmental samples were well over 5x those in the equipment blank; therefore, with the exception of TOC, contamination from the filter should be minimal for these samples. These data are included in Appendix D.

# 8.0. FILTERED SOLIDS DISCUSSION

This section presents a discussion of baseflow versus storm event results, spatial comparisons and the relationships between physical parameters and filtered solids chemical concentrations. Understanding how physical parameters (i.e., particle size distribution, flow, precipitation) can influence chemical results helps explain variability in the data that may not be directly related to seasonal or spatial factors.

## 8.1 Baseflow versus Storm Event Concentrations

This section examines differences in filtered solids baseflow and storm event data and addresses one of the study questions presented in Section 1: How do concentrations of PCBs, PAHs, dioxins/furans and arsenic associated with suspended solids within the Green River Basin differ between locations during baseflow and storm conditions<sup>21</sup>?

While only one baseflow filtered solids sample was collected at most sites, most samples were collected over several days and are potentially more representative of average baseflow conditions than a single grab sample. Even so, statistical comparisons between parameter concentrations in baseflow and storm event filtered solids samples were not possible, due to the limited sample numbers. Therefore, this section presents observations about baseflow concentrations relative to storm event concentrations.

Percent fines were typically highest in the baseflow samples, although at Soos Creek and Green River–Foster Links there were a few instances where percent fines were slightly higher in storm event samples compared to baseflow samples. This is not unexpected, because higher flow conditions are likely to keep larger particles in suspension or resuspend larger particles. As such, suspended solids collected during storm events are expected to have a larger fraction of larger grain size particles (e.g. sand) than baseflow samples. The majority of the storm event samples were still composed of fines.

Unlike the other metals evaluated, arsenic concentrations in baseflow filtered solids samples were about twice the average concentrations in storm event samples from Green River – Flaming Geyser, Mill Creek, and Green River–Foster Links, as well as in one baseflow sample from the Black River/Springbrook Creek basin. These finding suggests stormwater may not be a major pathway for particulate arsenic at these sites. This pattern of higher arsenic concentrations during baseflow conditions was also observed for whole water samples at some of these same locations (King County 2014a). Concentrations of all other metals, including mercury in baseflow samples were either within the range of storm event concentrations or lower than all storm event concentrations. The two exceptions to this pattern were mercury in Newaukum Creek and vanadium in Black River/Springbrook Creek basin, where baseflow concentrations were slightly higher.

<sup>&</sup>lt;sup>21</sup> The original intent was to compare dry season to wet season/storm conditions. However, because some baseflow samples were collected during the wet season, only comparisons between baseflow (dry and wet) and storm conditions could be considered.

For organic chemicals, baseflow concentrations were either lower or within the range of storm event concentrations, with the exception of total HPAHs, fluoranthene, and total PCBs in Soos Creek. At this site, baseflow concentrations were between 10 and 60% higher than the average storm event concentration. LPAHs and total PCB concentrations in whole water baseflow samples collected from Soos Creek during a previous study were also variable; much higher concentrations were detected in one of the three samples (King County 2014a). Additional data collection is necessary to further evaluate PCBs and PAHs in Soos Creek.

Baseflow concentrations of PAHs, PCBs, and total dioxin TEQs were within half the mean storm event concentration at all sites, except the Black River/Springbrook Creek basin and Green River–Foster Links, where differences were often greater. Additional baseflow data are necessary to determine if there are statistically significant differences in concentration between flow conditions.

The percent fines in all filtered solids samples at a given site varied by less than 20% (relative standard deviation) suggesting differences in percent fines did not likely influence observed differences in chemical concentrations between baseflow and storm events. Differences or influence of TOC could not be evaluated because TOC was not measured due to bias caused by the filter material. Section 8.3 discusses the potential impact of flow on variability of chemical concentrations between storm events.

## 8.2 Spatial Comparisons

This section examines spatial differences in filtered solids data and addresses one of the study questions presented in Section 1: What are the general spatial differences of PCBs, PAHs, dioxins/furans and arsenic in the major tributaries and the Green River? Only storm event samples were included in the spatial comparison; sample size was insufficient to adequately assess this question with baseflow samples.

Permutation tests were used to test differences in mean concentrations of arsenic, PAHs, PCBs<sup>22</sup>, and dioxin/furans and percent fines in storm event samples between the two Green River main stem sites, and then between the tributaries (See Section 4.3). Results of these analyses are presented in Figures 8-1 through 8-10<sup>23</sup>. The findings presented here are based on limited samples and thus there is higher uncertainty as to whether these samples sufficiently represent average conditions.

For the parameters assessed, no statistical differences were detected between the Green River main stem sites; mean and median concentrations were always higher at Green

<sup>&</sup>lt;sup>22</sup> PCB congeners were only analyzed in two and three storm event samples from Soos and Mill creeks, respectively. As such, only PCB congener data for Newaukum and Black River/Springbrook creeks were included in the statistical comparison between tributaries.

<sup>&</sup>lt;sup>23</sup> Figures illustrate statistical differences between sites with lower case letters for main stem differences and capital letters for tributaries (p<0.05).

River–Foster Links, but variability was also high. For all parameters, the range of concentrations overlapped between the main stem sites.

Mean storm concentrations in the Black River/Springbrook Creek basin were statistically different than Newaukum Creek (arsenic, PAHs, PCBs, dioxin TEQ and percent fines), Soos Creek (arsenic, PAHs, dioxin TEQ and percent fines), and Mill Creek (PAHs only). Mean and median storm event concentrations were highest (even when not statistically different) in the Black River/Springbrook Creek basin for all parameters assessed. Mean storm concentrations in Mill Creek were statistically different from those in Newaukum Creek for all assessed parameters except phenanthrene, LPAHs and dioxin TEQ. Mean storm concentrations were statistically different between Mill and Soos creeks for arsenic, benzo(b,j,k)fluoranthene, total HPAHs, total cPAHs, and total dioxin TEQs. No statistical differences were detected between Newaukum and Soos Creek storm event concentrations for the parameters assessed.



Figure 8-1. Statistical Comparison of Percent Fines in the Green River Main Stem and Tributaries during Storm Events



Figure 8-2. Statistical Comparison of Arsenic in the Green River Main Stem and Tributaries during Storm Events



Figure 8-3. Statistical Comparison of Total LPAHs in the Green River Main Stem and Tributaries during Storm Events



Figure 8-4. Statistical Comparison of Phenanthrene in the Green River Main Stem and Tributaries during Storm Events



Figure 8-5. Statistical Comparison of Total HPAHs in the Green River Main Stem and Tributaries during Storm Events



Figure 8-6. Statistical Comparison of Total cPAHs in the Green River Main Stem and Tributaries during Storm Events



Figure 8-7. Statistical Comparison of Benzo(b,j,k)fluoranthene in the Green River Main Stem and Tributaries during Storm Events



Figure 8-8. Statistical Comparison of Fluoranthene in the Green River Main Stem and Tributaries during Storm Events



# Figure 8-9. Statistical Comparison of Total PCBs in the Green River Main Stem and Tributaries during Storm Events



Figure 8-10. Statistical Comparison of Total Dioxin TEQs in the Green River Main stem and Tributaries during Storm Events

While the percent fines did not vary much between filtered solids samples, significant differences were detected between some sites (Figure 8-1). As discussed in Section 6.0, the differing percent fines content between sites could influence spatial comparisons. Correlation analysis with storm event results for all tributary sites combined showed all evaluated parameters were significantly, positively related to percent fines, except total LPAHs. This suggests differences in chemical concentrations between sites could be influenced in part by differences in percent fines. Significant correlations with storm event results for main stem sites combined were only detected between percent fines and three chemical concentrations (phenanthrene, total cPAHs, and total PCBs). The main stem Green River storm event data analyzed here were collected under a range of dam release conditions, which may have influenced results of the statistical analyses. This issue is discussed further in Section 8.3 below.

# 8.3 Relationships between Chemical Concentrations and Average Flow

Variability in flow may influence the characteristics of the suspended solids captured by the filtered solids sampling method. Chemical and flow data were evaluated to better understand the relationship between average flow conditions and observed chemical concentrations and help explain data variability that may not be directly related to seasonal or spatial factors.

Average flow during filtered solids collection was compared to associated storm event concentrations of arsenic, PAHs<sup>24</sup>, PCBs and dioxin/furan using non-parametric correlation analysis (Spearman Rank Test). Regression analysis was not a viable option, because average flow results had a skewed distribution at most sites. Because average flows often differed substantially between sampling locations, results from each site were compared separately. Flow data for Black River/Springbrook Creek and Mill Creek were not available, and thus, these sites were not included in the analysis. Additionally, due to a flow meter malfunction during collection of one Green River – Flaming Geyser sample, 4,000 cfs was used as an estimate (see Section 2.3.1).

Concentrations of all chemicals evaluated in Green River–Foster Links storm event samples were significantly, negatively related to average flow (Appendix E). Phenanthrene and total LPAH concentrations in Soos Creek storm event samples were significantly, negatively related to average flow. While most chemical concentrations at other sites were negatively associated with average flow, none were statistically significant. Appendix E presents all correlation analysis results.

Two storm event samples (03/05/2014 and 11/15/2015) were collected from the Green River main stem sites during major dam releases (>2,000 cfs at the USGS gage below the Howard Hanson Dam). While the USGS gage below the Howard Hanson Dam was not functioning during the 03/05/2014 sample collection, data from the downstream gage suggest flows were well over 2,000 cfs below the dam during this sampling event. Samples were collected from both main stem sites during this event, whereas only the Green River–Foster Links site was sampled on 11/15/2015.

At the upstream main stem site (Green River–Flaming Geyser), the 03/05/2014 sample had mostly moderate concentrations of chemicals when compared to the other storm samples at this site, which were all collected during lower flow conditions. Overall, this site had little variability in chemical concentrations across sampling events suggesting flow differences are not influencing chemical concentrations. There are two potential explanations for this. On one hand, local land use around this site is fairly undeveloped, similar to the area upstream of the dam. This means large dam releases would not substantially impact suspended solids chemical concentrations, because upland inputs are similar above and below the dam. Alternatively, local runoff might have limited impact on the chemical characteristics of storm samples, because the area below the dam is a relatively small portion of the total drainage area for this site; the largest portion is upstream of the dam.

Different results were found at the downstream site (Green River–Foster Links). Samples collected on 03/05/2014 and 11/15/2015, during a significant dam releases, had the lowest concentrations for most chemicals evaluated. In contrast, some of the highest chemical concentrations were detected during the two storm events with the lowest flows (least impacted from dam releases). The drainage areas close to the Green River–Foster

<sup>&</sup>lt;sup>24</sup> The PAHs included phenanthrene, fluoranthene, benzo(b,j,k)fluoranthene, total LPAHs, and total cPAHs.

Links site is urbanized whereas the upstream Green River site has only limited rural development. Based on the available data, the significant dam releases appear to be associated with lower chemical concentrations at the Foster Links site. This could be due to the larger contribution of suspended solids from the undeveloped areas upstream of the dam whereas, storm events with lower flows are more influenced by local runoff inputs. These local inputs likely have higher chemical concentrations due to larger contributions from more developed land use.

Figure 8-11 illustrates this concept for PCB concentrations compared to the average flow conditions during collection of filtered solids samples from the Green River–Foster Links. The total rainfall during the sampling period, and the 12 hours prior, are noted for sample groups. As described earlier, the lowest PCB concentrations were detected during the two storm events with the highest flows (indicating significant dam releases), while the highest concentrations were detected during the two storm event with relatively high rainfall, but lower flows (suggesting greater contributions from local runoff). USGS observed a similar pattern in a recent study that collected suspended solids samples from the same location, but using a centrifuge method (Conn et al. 2015). Median chemical concentrations in the USGS study were almost always lower during periods of higher dam release, than during storms without significant dam releases.



Figure 8-11. Relationship between Average Flow and Total PCB Concentrations in Green River– Foster Links Storm Event Samples

Because there are several interdependent variables affecting chemical concentrations (e.g., flow, percent fines, dam releases, stormwater runoff), future analysis using principal component analysis methods could be helpful to better understand relationships between parameters in this dataset.

# 9.0. METHOD COMPARISON SECTION

This section compares the three different sampling methods utilized in this study (baffle sediment trap, jar sediment trap, and filtered solids). Section 9.1 compares results from samples collected by baffle- and jar-style sediment traps, and Section 9.2 compares results from samples collected by baffle-style sediment traps and filtered solids methods.

# 9.1 Sediment Trap Method Comparison: Baffle vs. Jar

As described in Section 2.2.1, during each sediment trap deployment period, a jar-style trap sample was collected concurrently with a baffle-style trap sample at either Mill Creek (Period 1) or Green River–Foster Links (Periods 2 through 5). Comparison of these sampling methods included evaluation of the following parameters: percent fines, TOC, arsenic, phenanthrene, fluoranthene, pyrene, total PCB congeners, and total dioxin TEQs. Phenanthrene was selected as a representative LPAH because for each sampling period it was either detected or not detected in both sediment traps, making comparison across sampling types possible. Fluoranthene and pyrene were selected as representative HPAHs because they were detected in each paired sample.

Both sampling methods collect solids that travel through the water column. The baffle trap collects material as water passes through the sampling device, whereas material is collected in the jar as water passes over the opening. Based on field testing of these samplers in 2012, the baffle-style traps collected more material than the jar-style traps over the same deployment period. However, it is unknown how representative the material collected in each trap type is of the material suspended in the water column. Results from the two trap types were compared to understand the comparability of the data.

The percent fines content was not consistently greater in samples collected by either trap type (Figure 9-1). However, percent clay was almost always higher in samples collected by the jar-style trap. Concentrations of the remaining parameters assessed, including TOC, were always greater in jar-style trap samples, with the exception of arsenic (Period 5), phenanthrene (Period 3), and fluoranthene and pyrene (Period 4), when concentrations were similar or greater in the baffle-style trap samples (Table 9-1).



Figure 9-1. Comparison of PSD in Baffle and Jar Sediment Traps by Sample Period

# Table 9-1.Relative percent differences between analyte concentrations in the baffle and jar<br/>style sediment traps.

Analyte	Period	Sediment	RPD <sup>a</sup>		
Analyte	T CHOU	Baffle	Jar		
Total Fines (% by mass)	1	39.0	50.4	26%	
	2	17.6 J	17.6	0%	
	3	47.2 J	84.5	57%	
	4	33.7	23.0 J	38%	
	5	68.5 J 76.3 J		11%	
Clay (% by volume)	1	10.2	16.9	49%	
	2	3.10 J	5.20	51%	
	3	10.3 J	16.9	49%	
	4	3.50	3.40 J	3%	
	5	2.00 J	6.90 J	110%	
TOC (% dw)	1	1.79	2.85	46%	
	2	0.86	1.43	50%	
	3	3.09	3.71	18%	
	4	1.24	1.50	19%	
	5	3.00	4.42	38%	

Analyta	Poriod	Sediment	DDD a			
Analyte	Fenou	Baffle	Jar			
Arsenic (mg/kg dw)	1	6.21	9.93	46%		
	2	4.79	5.35	11%		
	3	12.0	13.7	14%		
	4	5.06	5.93	16%		
	5	17.5	19.3	10%		
Discontinues	1	22 J	26 J	15%		
	2	ND	ND	ND		
(ug/kg dw)	3	64.4	63.1	2%		
([29,9)	4	11.8	11.8	0%		
	5	27 J	34 J	26%		
	1	48.9	61.1	22%		
Elucronthono	2	10 J	17 J	53%		
(μα/kg dw)	3	161	169	5%		
(µg/Ng GW)	4	20.1	15.1	28%		
	5	66.6	83.6	23%		
Pyrene (ua/ka dw	1	48.1	66.3	32%		
	2	11 J	19.4	51%		
	3	159	168	5%		
	4	19.0	15.4	21%		
	5	83.2	109	27%		
	1	3.5 U <sup>b</sup>	5.2 J <sup>b</sup>	NA		
	2	0.700 J	1.33 J	62%		
(ug/kg dw)	3	12.0 J	14.9 J	22%		
(µg/g)	4	1.12 J	3.57 J	104%		
	5	11.5 J	31.0 J	92%		
Total Dioxin TEQs (ng TEQ/kg dw)	1	3.55 J	4.59 J	26%		
	2	0.516 J	0.660 J	24%		
	3	NA	NA	NA		
	4	NA	NA	NA		
	5	4.39 J	5.42 J	21%		
<ul> <li><sup>a</sup> Shaded cells indicate relative percent differences (RPDs) that exceed QC acceptance limits for laboratory replicates (PSD, TOC and arsenic = 20%; PAHs and PCBs = 35%; and dioxin/furans = 50%)</li> <li><sup>b</sup> Results based on PCB Aroclors</li> </ul>						

ND – non-detect; NA – not analyzed; J – estimated value; U – not detected

The differences in percent fines and TOC content between the two trap styles may have influenced the differences in chemical concentrations observed. To consider the significance of the observed differences, RPDs between sampling methods were calculated
for each sample pair (Table 9-1 and Figure 9-2).<sup>25</sup> Table 9-1 also indicates when the RPDs exceed the QC acceptance limits for variability between laboratory replicates as specified in the project SAP (QC acceptance limits are also displayed in dashed lines in Figure 9-2). Sample pair concentrations with RPDs within these QC limits can be considered reasonably similar, because they are within the allowable variability for analytical results from aliquots of the same sample. The RPDs for PSD and TOC often exceeded the acceptable analytical variability. The RPD QC acceptance limit for arsenic during Period 1 was exceeded, as was the RPD for PAHs during Period 2 and for PCBs during all periods except Period 3. The variability for dioxin TEQs was always within acceptable limits for laboratory variability.



Dashed lines indicate QC acceptance limits for variability between laboratory replicates.

# Figure 9-2. Relative Percent Difference between Chemical Concentrations in Paired Jar-Style and Baffle-Style Sediment Traps for each Sampling Period

In conclusion, baffle-style traps routinely collected material with lower percent fines, TOC content and chemical concentrations. The greatest differences were observed for PCB concentrations. However, differences between some the baffle and jar chemistry results were often within laboratory replicate QC acceptance criteria. Overall, baffle-style traps provided characterization with low bias compared to jar-style traps.

<sup>&</sup>lt;sup>25</sup> RPDs are calculated by dividing the difference between two sample results by the average of the two sample results. The fraction is then multiplied by 100% to convert to a percentage.

### 9.2 Baffle Sediment Trap vs. Filtered Solids Methods

There are several sampling methodology differences between the baffle sediment trap and filtered solids sampler. The baffle traps passively collected material over a three month period, whereas the filtration units pumped water over a relatively short time frame (3.5 to 48 hours; averaging ~ 20 hours) capturing specific events (baseflow or storms of varying intensity). The sediment trap samples at each site captured conditions over an extended period that included both dry and wet baseflows and storm event conditions. In addition, the filtration units are designed to capture all particles in the water greater than the filter pore size (5  $\mu$ m) whereas the traps are not expected to capture all particles across the size distribution of the suspended solids in the water column.

Although these differences exist, a general comparison of the physical and chemical characterization of suspended solids data collected by these two methods was conducted. This comparison can be used to inform future sampling methods to characterize suspended solids, as well as inform comparisons between datasets collected with different sampling methods. Only percent fines, percent clay, arsenic, phenanthrene, fluoranthene, total PCBs (based on congeners), and total dioxin TEQs were included in this analysis. Non-detect PAH results were included at the MDL value. Because of the non-detect results, the PAH findings are more uncertain than for parameters with 100% FOD. The figures used for this evaluation are included as Appendix H.

Results varied by parameter and site, but in many cases, filtered solids samples had the highest chemical concentrations and percent fines compared to baffle trap samples.<sup>26</sup> Results at the Springbrook Creek/Black River basin were the main exception, with baffle trap results always highest or within the range of filtered solids results.

At each site, non-parametric correlations were performed for percent fines and clay content versus chemical concentration. With the results from each sampling method combined, fines were occasionally correlated with chemical concentrations, but results were inconsistent (Appendix E). Therefore, while percent fines content may have influenced differences in chemical concentration between sampling methods at some sites (e.g., Green River – Flaming Geyser), correlation analysis results suggest there may be additional factors driving this pattern at other sites. One of these could be the difference in material collected during targeted storm sampling (i.e., the majority of filtered solids samples) versus sampling mixed precipitation and flow conditions over multiple months (i.e., sediment traps). Additionally, TOC was not analyzed in filtered solids samples due to bias from the sampling equipment; therefore, it is unknown how TOC concentrations may have influenced differences between sampling methods.

<sup>&</sup>lt;sup>26</sup> The percent fines and chemical concentrations were also lower in jar-style traps compared to the filtered solids.

Overall the data analysis suggests the filtered solids method may generally collect samples with higher fines content and chemical concentrations than the baffle sediment traps although in many cases there was some overlap in individual filtered solids sample results with baffle sediment trap results. In addition, these methods can only be generally compared because of the temporal and specific sampling methodology differences.

# **10.0. CONCLUSIONS**

This study presents an assessment of suspended solids quality in the Green River Watershed. The study provides a characterization of chemical concentration associated with suspended solids to better understand the relative differences between major tributary basins and the Green River during both dry conditions and wet season/storm events. Suspended solids samples were collected at two Green River main stem locations and four tributaries by two methods: baffle-style sediment traps and suspended solids collected on filters (filtered solids). More traditional jar-style sediment traps were also included (once per deployment period) for comparison to results from the baffle-style traps.

While the overall goal of this study was to better understand chemical characteristics of suspended solids upstream of the LDW, it was not designed to directly quantify contaminant loading from the Green River to the LDW. One reason for this is the uncertainty in how well each method characterizes the sediment that could deposit in the LDW from upstream. The sediment transport modeling for the LDW concluded that 90% of smallest-sized particles (clay and fine silt, <10 $\mu$ m) do not deposit in the LDW, but continue out to Elliott Bay<sup>27</sup> (QEA 2008). Seventy-eight percent of remaining fine particle size classes (medium/coarse silt, 10 to 62 $\mu$ m), are likely deposited in the LDW (QEA 2008). Because the current study did not parse out relative chemical concentrations between particle sizes, there is uncertainty in using these data to estimate the chemical characteristics of suspended sediments that deposit in the LDW. However, the data collected by this study, along with data from other studies (e.g., USGS study), can be used in the characterization of contaminants discharging to the LDW. The following summarizes the conclusions for the three study questions followed by additional findings and next steps.

### Question 1: What are the general chemical characteristics of suspended solids?

Samples were largely analyzed for key LDW contaminants of concern (arsenic, PAHs, PCBs and dioxins/furans). Average concentrations of these contaminants, as well as percent fines content, are listed in Table 10-1.

<sup>&</sup>lt;sup>27</sup> For reference, Table 3-1 in Section 3.1 presents the particle sizes binned in each size class.

Parameter	Location	Sedim	ent Traps	Filtered Solids		
i uluilotoi	Loouton	Jar-Style <sup>a</sup>	Baffle-Style <sup>b</sup>	Baseflow <sup>c</sup>	Storm <sup>d</sup>	
Fines	Green River – FG		36.0 J	73.4 J	54.0 J	
(% volume) <sup>e</sup>	Newaukum Creek		9.1 J	58.3	48.2	
	Soos Creek		20.0 J	57.2	51.4	
	Mill Creek	50.4	52.7 J	88.8	64.8	
	Black River/SC		78.7 J	87.3 J	75.4 J	
	Green River – FL	50.4 J	45.8 J	79.2 J	63.2 J	
Clay	Green River – FG	3.8 J		3.48 J	5.01 J	
(% volume)	Newaukum Creek		1.8 J	4.48	3.64	
	Soos Creek		2.0 J	2.57	2.77	
	Mill Creek	16.9	10.0 J	13.1	7.74	
	Black River/SC		22.1	13.9 J	9.72 J	
	Green River – FL	8.1 J	4.7 J	6.62 J	6.05 J	
Arsenic	Green River – FG		9.12	15.0	11.1	
(mg/kg dw)	Newaukum Creek		3.37	7.28	7.59	
	Soos Creek		5.32	9.64	11.0	
	Mill Creek	9.93	11.3	42.7	21.8	
	Black River/SC		49.4	47.5	35.5	
	Green River – FL	11.1	8.86	39.9	14.2	
Phenanthrene	Green River – FG		16 J	19.3	24.3 J	
(µg/kg dw)	Newaukum Creek		6.7 U	18.1	25.7	
	Soos Creek		14.5 J	52.2	48.2	
	Mill Creek	26 J	24 J	35.1	54.2	
	Black River/SC		187	120 J	271 J	
	Green River – FL	29.4 J <sup>f</sup>	27.8 J	23.7 J	73.6 J	
Fluoranthene	Green River – FG		10 J	16.4	15.8 J	
(µg/kg dw)	Newaukum Creek		7.1 J	31.5	49.1	
	Soos Creek	33.1 J		296 J	116 J	
	Mill Creek	61.1	64.7	109	152 J	
	Black River/SC		654	337 J	1,020	
	Green River – FL	71.2 J	64.3 J	60.6	187 J	

#### Table 10-1. Summary of sediment trap and filtered solids results.

Parameter	Location	Sedim	ent Traps	Filtered Solids				
		Jar-Style <sup>a</sup> Baffle-Style <sup>b</sup>		Baseflow <sup>c</sup>	Storm <sup>d</sup>			
Total cPAHs	Green River – FG		13 J	3.91 J	11.1 J			
(µg/kg dw)	Newaukum Creek		10 U	28.3 J	54.4 J			
	Soos Creek		19 J	82.0 J	70.4 J			
	Mill Creek	69.3 J	57.0 J	94.3 J	157 J			
	Black River/SC		672 J	439 J	916 J			
	Green River – FL	54.0 J	45.4 J	35.8 J	160 J			
Total PCBs	Green River – FG		0.363 J	1.48 J	2.93 J			
(µg/kg dw)	Newaukum Creek		0.209 J	5.78 J	3.60 J			
	Soos Creek		3.00 J	6.83 J	5.53 J			
	Mill Creek	5.2 J <sup>g</sup>	7.50 J	10.2 J	12.5 J			
	Black River/SC		44.4 J	38.1 J	116 J			
	Green River – FL	12.7 J	5.27 J	7.75 J	29.9 J			
Dioxin TEQs	Green River – FG		0.623 J	1.37 J	2.02 J			
(ng TEQ/kg dw)	Newaukum Creek		0.945 J	9.97 J	6.92 J			
	Soos Creek		2.06 J	5.31 J	6.08 J			
	Mill Creek	4.59 J	5.85 J	11.7 J	17.0 J			
	Black River/SC		16.6 J	10.2 J	21.9 J			
	Green River – FL	3.04 J	1.87 J	3.48 J	7.11 J			
<sup>a</sup> Jar-style sediment traps deployed at Mill Creek (Period 1) and Green River–Foster Links (Periods 2-5).								
<sup>c</sup> Mean of up to 5 sampling periods depending on parameter <sup>c</sup> Mean of 2 samples in Black River/Springbrook Creek basin and 3 samples at Green River-Foster								

Links; one sample at the other sites.

<sup>d</sup> Mean of up to 7 samples depending on parameter and location.

<sup>e</sup> Some trap results are based on percent mass. See Sections 3.1 and 5.1 for details.

<sup>f</sup> Phenanthrene not detected in Period 2 jar-style trap sample; sample is included in mean as the MDL.

<sup>g</sup> Based on detected PCB Aroclors.

See Tables 5.1 and 7.1 for sample numbers.

FG – Flaming Geyser; FL – Foster Links; SC – Springbrook Creek

-- - sample not collected; J – estimated value; U – non-detect; dw – dry weight; TEQ – toxicity equivalents

The chemistry results were also compared to the lowest site-wide LDW human health cleanup goals and the LDW point-based benthic cleanup goals. Concentrations in most of the filtered solids samples were greater than the LDW human health cleanup goals, while only a few concentrations in sediment trap samples were above these values (Table 10-2). This occurred most often at the three most downstream sites. Concentrations in a few Black River/Springbrook Creek basin samples were also above the LDW benthic cleanup goals for arsenic and PCBs. As previously described, the suspended solids characterized in this study are not equivalent to sediment deposited to bedded sediments in the LDW.

Therefore, this comparison is only intended to provide context for relative contaminant concentrations.

	Baffle Sediment Traps						Filtered Solids					
Parameter	FG	NC	SC	MC	SRC	FL	FG	NC	SC	MC	BR/ SRC	FL
Arsenic	4/5	0/5	1/5	4/5	2/2	2/5	6/6	4/6	5/6	6/6	6/6	10/10
Total cPAHs	0/5	0/5	0/5	0/5	2/2	0/4	0/5	0/6	0/6	0/6	5/6	1/9
Total PCBs	0/5	0/3	1/3	3/3	2/2	2/5	2/6	5/6	3/3	4/4	7/7	12/12
Dioxin TEQs	0/3	1/3	1/3	3/3	2/2	1/3	4/6	5/5	6/6	6/6	6/6	8/10

## Table 10-2.Number of samples above site-wide LDW human health cleanup goals for baffle<br/>sediment trap and filtered solids samples.

Data compared to LDW site-wide human health cleanup goals developed for consumption of resident seafood (total PCBs and Dioxin TEQs) and direct contact with sediment (arsenic and cPAHs)

FG = Green River – Flaming Geyser, NC = Newaukum Creek, SC = Soos Creek, MC = Mill Creek, BR = Black River; SRC = Springbrook Creek, FL = Green River–Foster Links.

# Question 2: How do concentrations differ between locations during dry season/baseflow and wet season/storm conditions for filtered solids?<sup>28</sup>

On average, percent fines content and arsenic concentrations were similar or higher in baseflow<sup>29</sup> samples than in storm samples. However, for organic chemicals, baseflow concentrations were similar or lower than average storm sample concentrations. Differences between baseflow and storm event chemical concentrations were most pronounced at Mill Creek, Black River/Springbrook Creek, and Green River–Foster Links. Although sample size is limited, the results suggest stormwater runoff may contribute suspended solids with elevated organic chemical concentrations, especially at the most downstream sites. The magnitude of influence on chemical concentrations in stormwater runoff depends on upland sources of chemicals and stormwater management (e.g., more urbanized land use tends to result in higher stormwater chemical concentrations than runoff from rural land use [Ecology 2011]).

### **Question 3: What are the spatial differences in chemical concentrations?**

Both the baffle sediment traps and filtered solids samples suggest some of the highest chemical concentrations are found in Mill Creek, the Black River/Springbrook Creek basin, and Green River–Foster Links. Chemical concentrations were generally highest in the Black River/Springbrook Creek basin. Chemical concentrations in baffle-style traps and filtered

<sup>&</sup>lt;sup>28</sup> Due to low sample size, this question could not be statistically addressed, but general observations were made.

<sup>&</sup>lt;sup>29</sup> While the baseflow samples are not all representative of dry ch conditions, none were collected during periods of rainfall, and should not include material from overland flow.

solids samples from the Green River–Foster Links were quite variable. For example, some concentrations at this site were similar to those in Black River/Springbrook Creek basin (site with highest concentrations), and others were within the range detected at the most upstream site, Green River – Flaming Geyser (site with relatively low concentrations). The potential influence of percent fines content, TOC and flow on these findings is discussed below.

### Influence of Percent Fines, TOC and Flow

Percent fines content, TOC (for sediment traps), and average flow during sampling periods were compared to sample chemical concentrations to better understand their potential influence on study results.

The percent fines and TOC content<sup>30</sup>of the samples may explain some of the variability in chemical concentration across collection periods at a given site. The highest chemical concentrations were almost always observed in sediment trap samples with highest percent fines and/or TOC. Although the percent fines measured in filtered solid samples were relatively similar across sites, higher chemical concentrations were generally observed in tributary samples containing higher levels of fine particles. This pattern was less consistent across the two main stem sites. The relationship between percent fines and chemical concentration is important to consider, because metals and organic chemicals are often preferentially associated with finer particles (Horowitz and Elrick 1987; Hedges and Keil 1995; Borglin et al. 1996).

Higher tributary flows are caused by precipitation and local runoff volumes. However, higher flows in Green River are associated with significant dam releases rather than increased local runoff from a rainfall event. While higher average flows were generally associated with lower chemical concentrations in filtered solids samples, relationships between flow and concentration at the tributary sites and Green River – Flaming Geyser were weak, and few were significant. However, at the downstream Green River –Foster Links site, concentrations of all chemicals evaluated were significantly, negatively correlated with average flow. More detailed analysis of the Green River–Foster Links data suggests chemical concentrations in filtered solids storm samples collected during significant dam releases (more flow from less developed area upstream of the dam) were lower than levels in storm samples collected during lower flows, but high rainfall (more flow from local runoff, with more developed land use). USGS observed a similar pattern in a recent study that collected suspended solids samples from the same location, but using a centrifuge method (Conn et al. 2015).

### **Method Comparisons**

A comparison of sediment trap sampling devices indicated that the percent fines and chemical concentrations in jar-style trap samples were generally higher than levels detected in paired baffle-style sediment trap samples. The differences in concentrations for

<sup>&</sup>lt;sup>30</sup> TOC was not analyzed in filtered solids samples due to false positives from the filter material; thus, chemical relationships to TOC could not be explored for these samples.

most parameters were relatively small (i.e., within the allowable limits for variability in laboratory replicates). The greatest difference in chemical concentrations between the two sample types were observed for total PCBs. The jar-style trap also tended to collect a slightly greater percentage of finer material with a higher TOC content than the baffle-style trap. This difference may have influenced differences in chemical concentrations. Overall, baffle-style traps provided characterization with low bias compared to jar-style traps (Section 9.1).

Results between filtered solids and baffle-style trap methods were compared at a high level. It is important to note that the sampling strategy differed greatly between these methods. Not only did the equipment differ, but sampling timespans were much different (i.e., two/three months versus less than 24 hours), and filtered solids targeted specific events (baseflow or storm) whereas sediment traps sampled a range of conditions. Filtered solids often had highest chemical concentrations, but the results often overlapped between sampling methods. In most cases, the filtered solids samples also had higher fines content, which could have influenced chemical concentrations.

### Next Steps

This study serves to improve the understanding of LDW contaminants of concern in suspended solids in the Green River Watershed and can be used to inform future source control efforts in the watershed. Ecology and EPA are currently conducting a Green/Duwamish Pollutant Loading Assessment where these data will be used. The Pollutant Loading Assessment is intended to identify upstream pollution sources as well as strategies to reduce those sources to support EPA's Lower Duwamish in-waterway cleanup. For example, data from this study, combined with data from other studies (Conn et al. 2015; Gries and Sloan 2009), can be used to estimate particulate<sup>31</sup> contaminant loadings to the LDW from upstream sources. However, the suspended solids data do not necessarily represent what settles in the LDW. The sediment transport model for the LDW estimated only 50% of the incoming material settles in the LDW and that percentage varies by particle size class (QEA 2008). In addition, variability in the data, especially as it relates to rainfall and flow patterns need to be considered. Therefore, to accurately determine the chemical composition of what settles in the LDW, additional analyses are necessary (e.g., chemical depositional analysis). Finally, data from this study and other relatively recent King County studies in the Green River Watershed (whole water, bedded sediment, and air deposition studies), serve to provide a better understanding of the location and magnitude of various contaminant levels and their pathways, and a better understanding of contaminant transport to the LDW.

<sup>&</sup>lt;sup>31</sup> These suspended solids results do not account for chemicals in the dissolved fraction, or the differences in chemical concentrations between particle sizes; therefore, total loads cannot be calculated with these particulate data alone.

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