Sediment Quality in the Green River Watershed

FINAL

February 2014

King County

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FINAL

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Wastewater Treatment Division

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Acknowledgements

We would like to acknowledge contributions to this study by the King County Environmental Laboratory (KCEL) and others. All sample collections were conducted by Jean Power with assistance from Stephanie Hess and Jeff Droker of the KCEL Field Science Unit. Laboratory project management was provided by Fritz Grothkopp of KCEL. All analytical procedures were conducted by KCEL except dioxin/furan analysis, which was conducted by AXYS Analytical Services, Ltd. Data validation of KCEL data was performed by Scott Mickelson. Validation of dioxin/furan congener data was conducted by Laboratory Data Consultants (LDC). Richard Jack provided database support for AXYS data. Jeffrey Stern provided valuable review of this report.

Citation

King County. 2014. Sediment Quality in the Green River Watershed. Prepared by Dean Wilson, Carly Greyell, and Debra Williston, King County Water and Land Resources Division. Seattle, Washington.

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Appendix B: SEM/AVS Calculations
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Acronyms

ANOVA	analysis of variance
AVS	acid volatile sulfides
BNAs	base/neutral/acid extractable semivolatile compounds
CSL	cleanup screening levels
CVAA	cold vapor atomic absorption
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
EPA	Environmental Protection Agency
GIS	geographic information system
HPAH	high molecular weight polycyclic aromatic hydrocarbon
KCEL	King County Environmental Laboratory
LDW	Lower Duwamish Waterway
LPAH	low molecular weight polycyclic aromatic hydrocarbons
MDL	method detection limit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyls
PSD	particle size distribution
QC	quality control
SAP	sampling and analysis plan
SCO	sediment cleanup objective
SEM	simultaneously extractable metals
SEM/AVS	simultaneously extractable metals/acid volatile sulfides
TEF	toxicity equivalent factor
TEQ	toxicity equivalent
TOC	total organic carbon
WAC	Washington Administrative Code

EXECUTIVE SUMMARY

King County is currently conducting several studies to characterize potential sources of contaminants of concern identified in the Lower Duwamish Waterway (LDW) Superfund site. These studies evaluate chemical concentrations in water, sediment and suspended solids in the Green River Watershed and in atmospheric deposition within the Green/Duwamish River Watershed that may contribute chemical inputs to the LDW. One of these is the streams sediment study presented here.

This study presents an assessment of sediment quality in the Green River Watershed to characterize chemical concentrations and to better understand the relative differences of sediment quality between tributary basins and the Green River. The sediment data will also provide information to assist in understanding upstream sources of chemicals to the Lower Duwamish Waterway, as inputs of sediments from the Green River Watershed are one of the long-term sources of contaminants to the Lower Duwamish Waterway.

Stream basins sampled included Mill Creek in Auburn, Mill Creek in Kent, Jenkins Creek, and Covington Creek in 2012 and Soos, Newaukum, and Springbrook Creeks in 2008-2010. Stream basin sampling sites were placed approximately every creek mile, where possible. Four Green River main stem locations were also sampled in 2012 and included an upstream location at Flaming Geyser State Park (upriver of the major tributaries being sampled), a downstream location at Foster Links Golf Course (downstream of the tributaries), and just upstream of Soos Creek and Mill Creek in Auburn. A total of 58 samples were analyzed. All sampling sites were located in depositional areas where fine sediments were present. All samples were analyzed for metals (including mercury) and organic chemicals such as polycyclic aromatic hydrocarbons, phthalates, polychlorinated biphenyls as Aroclors, and chlorinated pesticides. All samples were also analyzed for total organic carbon (TOC), total solids, particle size distribution, and simultaneously extractable metals/acid volatile sulfides (SEM/AVS) and a subset of samples were analyzed for dioxins/furans.

Overall, the relative differences between stream tributary basins as well as the Green River main stem locations shows that the more urbanized basins—Springbrook Creek, Mill Creek in Kent and to a lesser extent Mill Creek in Auburn—generally had higher concentrations of metals and organics and more exceedances of the Sediment Management Standards freshwater benthic sediment cleanup objective (SCO) criteria compared to less developed tributary basins and the Green River main stem locations.

Additional findings of this Green River Watershed sediment quality study are:

- All metals analyzed were detected in every sample; however, many organic compounds were infrequently or never detected.
- In all sediment samples, all chemical concentrations were below the Washington State Sediment Management Standards freshwater benthic cleanup screening level (CSL; the level expected to result in minor adverse effects to benthic [sediment-dwelling] organisms).

- Twenty-four of 58 samples had at least one chemical concentration above the Sediment Management Standards freshwater benthic SCO criteria, below which no adverse effects are expected for benthic organisms. Most SCO exceedances occurred at Mill Creek in Kent, followed by Springbrook Creek, then Mill Creek in Auburn. These three creek basins are more urbanized in comparison to other basins.
- In samples with metals concentrations above the SCO, SEM/AVS ratios indicated that metals were not bioavailable at about half the sampling locations. At locations where metals were not bioavailable they would not be expected to cause adverse effects to aquatic organisms.
- For most metals, Springbrook Creek followed by Mill Creek in Kent had the highest mean concentrations; however, significant differences in metal concentrations were not always observed between basins. In addition, Springbrook Creek and Mill Creek in Kent had more individual locations with higher organic compound concentrations, when detected, relative to other stream basins[1].
- PCBs were detected most often in Springbrook Creek, Mill Creek in Kent, and Mill Creek in Auburn. PCBs were either rarely or never detected in the remaining stream basins and Green River main stem sites. The highest concentrations were detected in Springbrook Creek and Mill Creek in Kent.
- With the exception of mercury, metal concentrations at all four Green River main stem sites were within a factor of two of each other. The five organic compounds detected in Green River main stem sites were within a factor of two of their respective detection limits; other organic compounds were not detected. This suggests very little difference between the four main stem sites.
- On average, sediment samples consisted of 50% or more sand particle sizes for all locations with the exception of Jenkins Creek, where sediment samples consisted of nearly 50% fine particles. Samples from the Green River locations generally had the lowest TOC and highest percent sand while samples from Jenkins Creek had the highest TOC and highest percent fines. Samples containing higher percentage of sand and lower TOC tend to have lower chemical concentrations.

[1] Statistical significance was not tested due to lower frequency of detection for organic compounds.

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1 INTRODUCTION

This study presents an assessment of sediment quality in the Green River Watershed to characterize chemical concentrations and to better understand the relative differences of sediment quality between tributary basins and the Green River. King County collected sediment samples to characterize bulk sediment chemical concentrations in seven stream basins that drain to the Green River and four locations on the Green River main stem. These sediments were characterized to evaluate sediment quality, to better understand the relative differences of sediment quality within streams in the Green River Watershed, and to allow comparison to other sample types collected in similar locations to determine usefulness in characterizing and tracking contaminant sources. The sediment data will also provide information to assist in understanding upstream sources to the Lower Duwamish Waterway (LDW), as inputs from the Green River Watershed are one of the long-term sources of contaminants to the Lower Duwamish Waterway.

This report is organized as follows: study background and study area (Section 1.0); sample collection and processing methods (Section 2.0); laboratory analytical methods (Section 3.0); data analysis (Section 4.0); data results (Section 5.0); discussion of the data (Section 6.0); and conclusions (Section 7.0). Referenced maps follow the report references. Supporting appendices include chain of custody forms, laboratory data results, and chemistry data validation reports. Sampling design, background, field and analytical methods, quality goals and objectives are documented in the study project sampling and analysis plan (SAP) (King County 2012).

1.1 Study Background

Understanding what is in sediments is important because chemical contaminants can be washed into streams and lakes from upland areas and attach to sediments, which then can settle to the bottom of a lake or stream. In this way, sediments can act as record of both historical and recent contaminants that have been discharged into surface waters. Once contaminants are in these bottom sediments they can persist where aquatic life (e.g., benthic or bottom-dwelling organisms) and people can be exposed to them directly or indirectly through consumption of fish or benthic organisms.

In 2004, King County began a ten-year stream sediment monitoring program to both characterize sediment quality and assess sediment quality trends in various creek basins in the King County wastewater service area, which includes the Green River Watershed and the Lake Washington Watershed. Stream basins where sediments were characterized were sampled approximately every creek mile from their mouth to their headwaters. Stream basins that were sampled for trends were sampled at a site near their mouth once every year. However, the stream sediment monitoring program was discontinued after 2010 due to budget reductions. Three creek basins in the Green River Watershed were sampled during this program and these data are being used in this current assessment of sediment quality in the Green River Watershed.

King County is a member of the Source Control Work Group for the LDW Superfund site. Other members include Washington Department of Ecology (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 in the waterway. King County wants to better understand the potential sources of contaminants of concern identified in the LDW Superfund site that may contribute chemical inputs to the LDW and is currently conducting several studies to evaluate chemical concentrations in water, sediment and suspended solids in the Green River Watershed (King County 2011a, King County 2013) and in atmospheric deposition within the Green/Duwamish River watershed (King County 2011b). The streams sediment study presented here is one of these studies and is intended to complement data from these other studies as well as present a characterization of stream sediments within the Green River Watershed. The bulk sediment chemical concentrations will also provide information to better understand the potential sources of sediment-associated chemicals to the Green and Duwamish Rivers.

1.2 Study Area Streams

The 58 stream locations sampled in this sediment quality assessment are shown in Map 1. Samples were collected in 2012 in Mill Creek in Auburn, Mill Creek in Kent, Jenkins Creek, and Covington Creek, and at four locations on the main stem Green River. The most upstream location on the Green River (upriver of the major tributaries being sampled) is at Flaming Geyser State Park, while the most downstream location on the Green River (downstream of the tributaries) is at the Foster Links Golf Course in Tukwila. The other two locations on the Green River are just upstream of Soos Creek and just upstream of Mill Creek in Auburn. Samples were also collected from Soos, Newaukum, and Springbrook Creeks in 2008-2010; these creeks were sampled, as noted earlier, as part of a now discontinued stream sediment monitoring program. Data collected to characterize the creek basins are included but sediment data collected to assess trends, a component of the stream sediment monitoring program, are not included. This is because the program was discontinued before there were sufficient samples to evaluate chemistry trends in the stream sediments sampled.

Map 2 shows land use categories for the Green/Duwamish River Watershed. Land use varies for tributary basins and the main stem of the Green River from highly urbanized (mix of commercial/industrial/residential urban) to predominantly residential rural and natural resources.

2 FIELD COLLECTION METHODS

This section provides an overview of the field collection methods used in this study. All field collection was conducted by the King County Environmental Laboratory (KCEL). The sampling collection and processing methods are summarized in Section 2.1, and the sample locations and station identifiers are described in Section 2.2. Copies of completed chain of custody forms used to track sample custody are included in Appendix A.

The sampling collection and processing methods summarized below were also used during the 2008-2010 stream sampling events.

2.1 Sample Collection and Processing

Samples were collected using a pre-cleaned PVC core tube to penetrate stream bottom sediments to a depth of 5 to 10 centimeters. A stainless steel spatula or gloved hand was inserted under the core tube mouth to trap the sediment inside, and the tube was removed from the stream. Water was slowly drained so as not to allow any fines to escape. The sediment in the tube was then transferred into a stainless steel bowl for compositing. This process was repeated a minimum of five times for each sampling station to acquire an appropriate amount of material to fill all sample containers after compositing and to obtain sediment from a depositional area of at least two to three meters in diameter when it was possible. If core tube penetration was poor or streambed was rocky or gravelly, or if additional sediment volume was needed to fill all sample containers, additional core tubes were collected. If fine sediments at the sampling site were present but were confined to an area smaller than approximately 3”x 3”, a pre-cleaned stainless steel spoon was used to acquire sediment for compositing instead of the core tube method. A stainless steel spoon or spatula was used to homogenize the sample by stirring. Rocks or other debris a half inch in diameter or larger were removed and discarded. All sampling equipment (PVC core tube, stainless steel spatulas, spoons, and bowls) were all pre-cleaned[2] and a set was dedicated to each sampling station.

At the Foster Links site on the Green River main stem, sediment was collected from the top 5 to 10 centimeters using a petite ponar sampler lowered from the golf cart bridge over the river. Three casts were collected and composited before the sample was homogenized and split.

Once the sediment was collected, composited, and homogenized in a stainless steel bowl, sample jars for individual analyses were filled in the field from the composited sample using a pre-cleaned stainless steel spoon. Sample jars were pre-labeled and once they were filled they were capped and placed in coolers on ice for transport to the KCEL. Chain of custody was maintained at all times. Chain of custody documentation appears in Appendix A.

[2] Equipment was pre-cleaned with detergent 8, soaking in a 5 % acid solution, and finally rinsed with deionized water; stainless steel equipment did not include the acid solution rinse.

2.2 Sample Locations and Station Identifiers

Likely sampling stations were identified using King County's GIS aerial photos and streams coverage. Access logistics and property ownership of a likely sampling site were screened and driving directions were developed. Access permission was obtained from property owners where appropriate. Sampling sites were placed every creek mile, where possible, based on King County's GIS creek mile coverage. Project staff then visited each site during a field reconnaissance trip. Sampling sites were located in depositional areas where fine sediments were present. Actual sampling locations were shifted upstream or downstream based on the presence of fine sediment availability. If a site turned out to be inaccessible, an attempt was made to add another site within the same creek mile. If no access was available along that creek mile then that creek mile was not sampled. Once likely sites were identified, a GIS locator (Washington state plane North NAD 83) was recorded for each site and a unique station locator was created. Where possible, existing station locators were used. Project staff returned later to each site to collect sediment samples using information collected during the field reconnaissance. Locators, location coordinates and sample collection dates for both the 2012 samples and the previously collected samples in 2008-2010 are listed in Table 1. Locations of all 58 sampling stations are shown on Map 1.

Table 1. Stream Sediment Station Locations and Sample Collection Dates

Station Locator	Creek[a]	State Plane Easting	State Plane Northing	Sample Collection Date
0320[b]	Big Soos Creek	1309035	115400	7/26/2010
A320	Big Soos Creek	1309972	116821	7/26/2010
AA320	Big Soos Creek	1317684	125229	7/26/2010
GG320	Big Soos Creek	1317645	128035	7/26/2010
HH320	Big Soos Creek	1315790	137405	7/26/2010
II320	Big Soos Creek	1315845	143630	7/26/2010
L320	Big Soos Creek	1311576	155792	7/26/2010
P320	Big Soos Creek	1316205	140841	7/26/2010
Q320	Big Soos Creek	1319226	133287	7/26/2010
RR320	Big Soos Creek	1312470	149220	7/26/2010
SS320	Big Soos Creek	1312305	154955	7/26/2010
AB320	Covington Creek	1321350	119105	8/14/2012
C320	Covington Creek	1327045	116490	8/14/2012
CC320	Covington Creek	1324280	116570	8/14/2012
CD320	Covington Creek	1329470	113590	8/15/2012
PT320	Covington Creek	1338290	122575	8/15/2012
S320	Covington Creek	1346550	126070	8/15/2012
Z320	Covington Creek	1339866	124875	8/15/2012
0318	Green River	1294280	134927	8/29/2012
A319	Green River	1307302	113108	8/27/2012
FG319	Green River	1341097	104038	8/14/2012

Station Locator	Creek[a]	State Plane Easting	State Plane Northing	Sample Collection Date
FL319	Green River	1288012	177997	8/29/2012
D320	Jenkins Creek	1319039	126881	8/15/2012
FR320	Jenkins Creek	1326790	137155	8/27/2012
JK320	Jenkins Creek	1325834	133151	8/27/2012
LW320	Jenkins Creek	1339395	140055	8/27/2012
WX320	Jenkins Creek	1322235	129990	8/27/2012
A315	Mill Creek (Auburn)	1289725	137218	8/13/2012
ED315	Mill Creek (Auburn)	1290545	122530	8/13/2012
FR315	Mill Creek (Auburn)	1290680	129960	8/29/2012
PC315	Mill Creek (Auburn)	1281940	117340	8/14/2012
PR315	Mill Creek (Auburn)	1287170	113555	8/14/2012
SD315	Mill Creek (Auburn)	1289415	133275	8/13/2012
TS315	Mill Creek (Auburn)	1290765	127160	8/13/2012
UH315	Mill Creek (Auburn)	1281775	118130	8/14/2012
AA318	Mill Creek (Kent)	1294800	146780	8/28/2012
CS318	Mill Creek (Kent)	1292480	150045	8/28/2012
DT318	Mill Creek (Kent)	1291450	158960	8/27/2012
EG318	Mill Creek (Kent)	1301075	135305	8/28/2012
EP318	Mill Creek (Kent)	1295940	142700	8/28/2012
FS318	Mill Creek (Kent)	1291205	155285	8/28/2012
IT318	Mill Creek (Kent)	1292010	163195	8/30/2012
SH318	Mill Creek (Kent)	1299685	137710	8/28/2012
0322[b]	Newaukum Creek	1334258	105523	8/10/2009
E322	Newaukum Creek	1340907	90871	8/10/2009
X322	Newaukum Creek	1334258	105523	8/10/2009
F322	Newaukum Creek	1342797	85546	8/10/2009
FF322	Newaukum Creek	1342468	82948	8/10/2009
G322	Newaukum Creek	1351043	82823	8/10/2009
QQ322	Newaukum Creek	1357235	85390	8/10/2009
BB322	Newaukum Creek	1341445	93565	8/10/2009
AD322	Newaukum Creek	1346405	79610	8/10/2009
AE322	Newaukum Creek	1347765	80264	8/10/2009
0317[b]	Springbrook Creek	1294315	173079	7/28/2008
K317	Springbrook Creek	1295535	169340	8/5/2008
L317	Springbrook Creek	1292645	164190	8/5/2008
M317	Springbrook Creek	1294345	161415	8/5/2008
N317	Springbrook Creek	1295325	160440	8/5/2008

[a] Samples from Soos, Newaukum and Springbrook Creeks collected in 2008-10
[b] Re-sampled for dioxin/furans in August 2012

3 LABORATORY ANALYSIS AND METHODS

All samples were analyzed for metals (including mercury), base/neutral/acid extractable semivolatile compounds, four endocrine disrupting compounds (4-nonylphenol, bisphenol A, bis(2-ethylhexyl)adipate, coprostanol), polychlorinated biphenyls as Aroclors, chlorinated pesticides, total organic carbon (TOC), total solids, particle size distribution, and simultaneously extractable metals/acid volatile sulfides (SEM/AVS). A subset of samples collected four stations (Mill Creek in Auburn and Mill Creek in Kent at the stations closest to the mouths of the streams, and from the Green River at the station farthest upstream [Flaming Geyser] and the farthest downstream [Foster Links golf course]) were analyzed for dioxins/furans. The samples that were previously collected from Soos, Newaukum, and Springbrook Creeks in 2008-2010 were analyzed for all of the parameters listed above except dioxins/furans. Therefore, a sample was collected at the mouths of each these streams (Soos, Newaukum, and Springbrook) for analysis of dioxins/furans.

Laboratory analyses were conducted by KCEL except dioxin/furan congeners, which were analyzed by AXYS Analytical Services, Ltd.

Conventional parameters that were analyzed included particle size distribution (PSD), pH, total solids, total organic carbon (TOC) and acid volatile sulfides (AVS). Analytical methods are listed in Table 2.

Table 2. Conventional Analysis Methods

Parameter	Method
PSD (gravel and sand)	ASTM D422
PSD (silt and clay)	ASTM D422
Total Organic Carbon	EPA 9060, PSEP 1996
pH	SW846 9045D
Total Solids	SM 2540-G
Acid Volatile Sulfide	EPA 1991

Metals parameters analyzed for this study included simultaneously extractable metals (SEM for arsenic, cadmium, copper, lead, mercury, nickel, silver, and zinc) and total metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc). The total metals analysis method for metals not including mercury was inductively couple plasma mass spectroscopy method SW846 3050B/6020A. Total mercury analysis was done by cold vapor atomic absorption (CVAA) method EPA 7471B. SEM metals, except mercury, were analyzed by inductively coupled plasma atomic emission spectroscopy method EPA 821 1991/200.7. SEM mercury was analyzed by CVAA method MT EPA 821 1991/245.1*SW846 7470A

Organic parameters analyzed for this study included base/neutral/acid extractable semivolatile compounds (BNAs), endocrine disrupting compounds (4-nonylphenol, bisphenol A, bis(2-ethylhexyl)adipate, coprostanol), chlorinated pesticides, and PCBs (as

Aroclors). BNA analysis included compounds such at high and low molecular weight polyaromatic hydrocarbons (LPAHs and HPAHs). BNA compounds were analyzed using EPA method SW 846 3550C/8270D. Chlorinated pesticides, such as DDT, and PCBs were analyzed using EPA method SW 846 3550C/8081B/8082A. Endocrine disrupting compounds were analyzed using method SW846 3550B/ 8270D.

A total of seventeen dioxin/furan congeners were analyzed by EPA method 1613b, which is a high-resolution gas chromatography/high-resolution mass spectroscopy method using an isotope dilution internal standard quantification.

All analytical laboratory methods followed those described in the SAP with the following exception: SEM mercury was analyzed by method MT EPA 821 1991/245.1*SW846 7470A. The method listed in the SAP was a clerical error.

4 DATA ANALYSIS

The analytical concentration data were prepared for data analysis by calculating sums for certain analyte groups (e.g., PAH, PCB and DDT) and dioxin toxicity equivalents or TEQs. In addition, SEM/AVS ratios were calculated. The method used for these calculations are described in this section. In addition, the 2013 Washington State Sediment Management Standards for protection of freshwater benthic invertebrates are also presented for those analytes with criteria. Finally, a description of the statistical analysis performed is provided.

4.1 Summation for PAHs, PCBs and Organo-Chlorine Pesticides

For certain compounds, total concentrations were calculated for comparison to sediment standards and to summarize and compare data among stream sampling locations. These include total PAHs, total PCBs, total DDTs, total DDEs and total DDDs. Total PAHs were calculated by summing detected concentrations of 17 individual PAH results. The PAHs summed were: 1-methylnaphthalene, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, benz(a)anthracene, benzo(a)pyrene, benzo(ghi)perylene, chrysene, dibenz(ah)anthracene, fluoranthene, fluorene, indeno(123-cd)pyrene, naphthalene, phenanthrene, pyrene, total benzofluoranthenes (b.+k.+j). Total PCBs were calculated summing detected Aroclors, and total DDT, DDE and DDD were also calculated by summing the detected isomers. When all results are nondetect, the total is based on the single highest nondetect value (U-flagged).

4.2 Dioxin TEQs

Dioxin and furan congener data were converted to toxicity equivalents (TEQs) because TEQs provide a toxicity-based approach to interpreting the dioxin and furan congener data. Dioxin and furan congener concentrations were converted to TEQs 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) (see Table 3) to result in a TEQ concentration. 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 non-detect value (or U qualified value)[1].

[1] For laboratory results qualified as "K" by AXYS, 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.

Table 3. TEFs Applied in Calculation of Dioxin TEQs

Compound	TEF
Dioxins	
2,3,7,8-TCDD	1
OCDD	0.0003
1,2,3,4,6,7,8-HPCDD	0.01
1,2,3,4,7,8-HXCDD	0.1
1,2,3,6,7,8-HXCDD	0.1
1,2,3,7,8,9-HXCDD	0.1
1,2,3,7,8-PECDD	1
Furans	
2,3,7,8-TCDF	0.1
1,2,3,4,6,7,8-HPCDF	0.01
1,2,3,4,7,8,9-HPCDF	0.01
1,2,3,4,7,8-HXCDF	0.1
1,2,3,6,7,8-HXCDF	0.1
1,2,3,7,8,9-HXCDF	0.1
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

4.3 SEM/AVS Ratios

SEM/AVS metals ratios were calculated to better understand the bioavailability of metals in sediment samples (DiToro et al., 1990 and Hansen et al., 2005). The bioavailability of metals is influenced by the presence of AVS. AVS binds to metals in sediments and sequesters them, making the bound metal unavailable for biological uptake. Basically, to calculate SEM/AVS ratios, the molar concentration of SEM metals (cadmium, copper, lead, nickel, silver and zinc) present in a sample are added together and divided by the molar concentration of AVS present in that same sample. If less SEM metals than AVS are present (ratio of less than 1), then the metals in the sample are likely to not be bioavailable. This SEM/AVS ratio was calculated for each sample and the bioavailability of metals in each sample was assessed. SEM/AVS calculation tables appear in Appendix B and discussion of SEM/AVS analyses are presented in Section 6.2.

4.4 Washington State Freshwater Sediment Management Standards

Data results were compared to Washington State Sediment Management Standards, table VI, Freshwater Sediment Cleanup Objectives (SCO) and Cleanup Screening Levels (CSL) Chemical Criteria (WAC 173-204-563; Ecology 2013). Table 4 presents the numeric benthic criteria; these freshwater standards became effective September 1, 2013.

Table 4. Freshwater Sediment Numeric Chemical Criteria for Benthic Organisms

Chemical Parameter	Dry Weight	
	Sediment Cleanup Objective	Cleanup Screening Level
Conventional Chemicals (mg/kg)		
Ammonia	230	300
Total sulfides	39	61
Metals (mg/kg)		
Arsenic	14	120
Cadmium	2.1	5.4
Chromium	72	88
Copper	400	1200
Lead	360	> 1300
Mercury	0.66	0.8
Nickel	26	110
Selenium	11	> 20
Silver	0.57	1.7
Zinc	3200	> 4200
Organic Chemicals (µg/kg)		
4-Methylphenol	260	2000
Benzoic acid	2900	3800
Beta-Hexachlorocyclohexane	7.2	11
Bis(2-ethylhexyl) phthalate	500	22000
Carbazole	900	1100
Dibenzofuran	200	680
Dibutyltin	910	130000
Dieldrin	4.9	9.3
Di-n-butyl phthalate	380	1000
Di-n-octyl phthalate	39	> 1100
Endrin Ketone	8.5	> 8.5
Monobutyltin	540	> 4800
Pentachlorophenol	1200	> 1200
Phenol	120	210
Tetrabutyltin	97	> 97
Total PCB Aroclors	110	2500
Total DDDs	310	860

Chemical Parameter	Dry Weight	
	Sediment Cleanup Objective	Cleanup Screening Level
Total DDEs	21	33
Total DDTs	100	8100
Total PAHs	17000	30000
Tributyltin	47	320
Bulk Petroleum Hydrocarbons (mg/kg)		
Total Petroleum Hydrocarbon (TPH)-Diesel	340	510
Total Petroleum Hydrocarbon (TPH)-Residual	3600	4400

Spatial analysis of sediment data was conducted by plotting potential effects codes at each sampling location on a map (see Section 6.1). Effects codes were developed by comparing chemical data results to sediment management standards shown in Table 4. If a sample had one or more chemical concentrations that exceeded the SCO, then the locator was colored yellow. If a sample had one or more chemical concentrations that exceeded the CSL then the locator was colored red. If a sample had no chemical concentrations that exceeded the SCO then the locator was colored green. Chemical concentrations at or below the SCO correspond to sediment quality that results in no adverse effects to the benthic community, whereas the CSL establish at least minor adverse effects level to the benthic community (WAC 173-204-563).

4.5 Statistical Methods

Metal concentrations for each basin were statistically compared using Sigma Plot 12.0 software. Parametric tests were used when data passed both the Shapiro-Wilk Normality test ($p<0.05$) and Equal Variance test ($p<0.05$). Parametric tests included analysis of variance (ANOVA) followed by Holm-Sidak comparison method ($p<0.05$). Nonparametric tests included ANOVA on Ranks followed by Dunn's comparison method ($p<0.05$). Organic compounds were not included in statistical tests because frequency of detection was less than 100% and sample sizes per stream basin were too small to reliably perform any estimates for the non-detected organic compounds for statistical analysis. Graphical results of the statistical analyses are presented in Section 6.3.

5 RESULTS

This section provides a summary of the analytical results and summary of data validation findings for 2012 chemistry analyses. All analytical data as reported by the laboratories are presented in Appendix C and data validation reports are included in Appendix D.

A total of 58 sediment samples were collected from seven creeks and the Green River for this assessment. The creeks sampled were Newaukum, Covington, Jenkins, Big Soos, Mill (in Auburn), Mill (in Kent), and Springbrook. A total of ten samples were collected in Newaukum, seven were collected from Covington, five were collected from Jenkins, eleven samples were collected in Big Soos, eight were collected from Mill Creek in Auburn, eight were collected in Mill Creek in Kent, five were collected in Springbrook, and four were collected in the Green River.

5.1 Data Summaries

Data summaries are presented for metals, total PCBs, PAHs, phthalates, particle size distribution, total organic carbon, and dioxin TEQs. Summaries include minimum and maximum detected concentrations and mean and median concentrations by creek basin and all sites combined. Summaries were not compiled for chlorinated pesticides and endocrine disrupting compounds because there were too few detections.

The most frequently detected endocrine disrupting chemical was 4-nonylphenol. This compound was detected in 20% of the samples with the majority of detections at Mill Creek in Kent, Mill Creek in Auburn and Springbrook Creek. Bis(2-ethylhexyl)adipate was the next most frequently detected, but was only found in Newaukum Creek. No endocrine disrupting chemicals were detected in Jenkins Creek or Soos Creek.

The most commonly detected pesticide compounds were DDD and DDT, but both were detected in less than 7% of samples. The majority of pesticide detections occurred at Mill Creek in Kent and Springbrook Creek. No pesticide compounds were detected in Covington Creek, Soos Creek or the Green River.

Table 5 summarizes sediment metal concentrations by creek/river basin. Metals were detected in all samples. Springbrook Creek had the highest observed concentrations of chromium, copper, nickel, silver, and zinc while the maximum concentrations of cadmium and lead were found in Mill Creek in Kent. Soos Creek had the highest maximum concentration of arsenic and the Green River had the highest mercury concentration. Map 3 illustrates the spatial distribution of arsenic concentrations. This map is intended to provide spatial context for the concentration of arsenic, which is a key contaminant of concern for the Lower Duwamish Waterway based on human health risks.

Table 5. Green River Watershed Sediment Metals Concentrations (mg/kg dry weight) Summary Statistics

Metal	Creek	FOD	Min	Max	Mean	Median
Arsenic	Newaukum Creek	10/10	2.41	7.33	4.42	4.51
	Covington Creek	7/7	0.706	19.5	5.17	3.12
	Jenkins Creek	5/5	2.53	10.7	5.77	4.64
	Soos Creek	11/11	2.93	63.6	14.2	7.12
	Mill Creek Auburn	8/8	4.13	26.4	12.6	12.2
	Mill Creek Kent	8/8	2.92	17.6	8.01	5.82
	Springbrook Creek	5/5	11.5	56.6	25.5	22.1
	Green River	4/4	3.22	4.84	4.08	4.14
	All Sites Combined	58/58	0.706	63.6	9.89	4.99
Cadmium	Newaukum Creek	10/10	0.0758	0.278	0.146	0.143
	Covington Creek	7/7	0.030	0.165	0.075	0.060
	Jenkins Creek	5/5	0.229	0.579	0.432	0.497
	Soos Creek	11/11	0.0518	0.738	0.170	0.075
	Mill Creek Auburn	8/8	0.119	0.684	0.327	0.334
	Mill Creek Kent	8/8	0.259	3.94	1.14	0.782
	Springbrook Creek	5/5	1.16	3.42	2.22	2.28
	Green River	4/4	0.054	0.0777	0.0666	0.0673
	All Sites Combined	58/58	0.030	3.94	0.501	0.193
Chromium	Newaukum Creek	10/10	9.57	29.4	18.4	18.5
	Covington Creek	7/7	3.10	30.3	13.3	12.5
	Jenkins Creek	5/5	6.91	20.1	13.1	12.4
	Soos Creek	11/11	8.18	27.5	18.9	21.0
	Mill Creek Auburn	8/8	9.29	32.9	16.8	13.2
	Mill Creek Kent	8/8	8.41	40.9	21.4	21.0
	Springbrook Creek	5/5	22.9	46.2	34.8	36.4
	Green River	4/4	9.00	14.9	11.6	11.2
	All Sites Combined	58/58	3.10	46.2	18.5	16.6
Copper	Newaukum Creek	10/10	11.6	37.0	20.7	20.2
	Covington Creek	7/7	1.93	13.9	9.10	10.1
	Jenkins Creek	5/5	8.59	26.7	18.4	18.8
	Soos Creek	11/11	4.71	25.8	11.6	10.2
	Mill Creek Auburn	8/8	8.26	36.7	20.0	18.6
	Mill Creek Kent	8/8	11.3	52.9	34.7	33.7
	Springbrook Creek	5/5	31.1	112	56.4	52.2
	Green River	4/4	10.6	17.2	13.9	13.9
	All Sites Combined	58/58	1.93	112	21.8	17.5

Metal	Creek	FOD	Min	Max	Mean	Median
Lead	Newaukum Creek	10/10	3.48	17.8	8.29	7.14
	Covington Creek	7/7	1.78	11.4	5.63	3.11
	Jenkins Creek	5/5	11.5	25.5	18.3	16.3
	Soos Creek	11/11	2.79	37.5	12.2	5.51
	Mill Creek Auburn	8/8	8.09	48.9	19.9	14.7
	Mill Creek Kent	8/8	21.0	66.5	40.2	33.5
	Springbrook Creek	5/5	25.6	60.5	40.1	43.1
	Green River	4/4	2.30	5.28	3.68	3.58
	All Sites Combined	58/58	1.78	66.5	18.0	12.1
Mercury	Newaukum Creek	10/10	0.015	0.073	0.035	0.033
	Covington Creek	7/7	0.014	0.065	0.036	0.027
	Jenkins Creek	5/5	0.063	0.19	0.12	0.11
	Soos Creek	11/11	0.017	0.210	0.053	0.031
	Mill Creek Auburn	8/8	0.015	0.13	0.070	0.071
	Mill Creek Kent	8/8	0.063	0.11	0.090	0.095
	Springbrook Creek	5/5	0.069	0.16	0.11	0.096
	Green River	4/4	0.011	0.540	0.17	0.062
	All Sites Combined	58/58	0.011	0.540	0.074	0.063
Nickel	Newaukum Creek	10/10	5.88	25.8	13.9	12.7
	Covington Creek	7/7	2.33	24.0	12.7	14.4
	Jenkins Creek	5/5	5.49	12.1	9.83	11.1
	Soos Creek	11/11	9.87	36.4	20.5	19.0
	Mill Creek Auburn	8/8	7.20	28.9	16.3	12.3
	Mill Creek Kent	8/8	5.96	19.4	13.7	14.3
	Springbrook Creek	5/5	16.2	38.4	25.6	21.7
	Green River	4/4	10.5	20.0	13.9	12.7
	All Sites Combined	58/58	2.33	38.4	16.0	14.1
Silver	Newaukum Creek	10/10	0.038	0.14	0.074	0.074
	Covington Creek	7/7	0.0096	0.043	0.027	0.030
	Jenkins Creek	5/5	0.046	0.091	0.074	0.074
	Soos Creek	11/11	0.018	0.12	0.042	0.032
	Mill Creek Auburn	8/8	0.028	0.13	0.080	0.0825
	Mill Creek Kent	8/8	0.051	0.227	0.125	0.140
	Springbrook Creek	5/5	0.131	0.365	0.217	0.178
	Green River	4/4	0.023	0.0450	0.036	0.039
	All Sites Combined	58/58	0.0096	0.365	0.080	0.055

Metal	Creek	FOD	Min	Max	Mean	Median
Zinc	Newaukum Creek	10/10	42.3	126	77.7	71.7
	Covington Creek	7/7	7.02	81.0	34.7	34.5
	Jenkins Creek	5/5	42.8	113	79.5	80.8
	Soos Creek	11/11	29.4	189	68.1	46.3
	Mill Creek Auburn	8/8	50.1	180	123	129
	Mill Creek Kent	8/8	108	532	307	297
	Springbrook Creek	5/5	173	954	462	397
	Green River	4/4	33.0	66.5	47.2	44.7
	All Sites Combined	58/58	7.02	954	140	83.0

FOD = Frequency of Detection

Table 6 summarizes sediment total PCB concentrations by creek/river basin. PCBs were not detected in Green River and Newaukum Creek and were infrequently detected in Covington, Jenkins and Soos Creeks. PCBs were detected in all five samples of Springbrook Creek and most samples from Mill Creeks in Auburn and Kent. Detected PCB concentrations in individual samples ranged from 1.9 µg/kg dry weight in Soos Creek to 128 µg/kg dry weight in Mill Creek in Kent. Mill Creek in Kent and Springbrook Creek had samples with the highest concentrations of total PCBs at 128 and 117 µg/kg dry weight, respectively. Map 4 illustrates the spatial distribution of total PCB concentrations. This map is intended to provide spatial context for the concentration of total PCBs, which is a key contaminant of concern for the Lower Duwamish Waterway based on human health and ecological risks.

Table 6. Green River Watershed Sediment Total PCB Concentrations (µg/kg dry weight) Summary Statistics

	Creek	FOD	Min	Max	Mean[a]	Median[a]
Total PCBs (as Aroclors)	Newaukum Creek	0/10	n/a	4U	n/a	n/a
	Covington Creek	1/7	n/a	3.8	n/a	n/a
	Jenkins Creek	1/5	n/a	63.0	n/a	n/a
	Soos Creek	1/11	n/a	1.9	n/a	n/a
	Mill Creek Auburn	4/8	9.3	31	19	17
	Mill Creek Kent	7/8	17.4	128	56.9	51.8
	Springbrook Creek	5/5	12.8	117	59.0	54.0
	Green River	0/4	n/a	5.5U	n/a	n/a
	All Sites Combined	19/58	1.90	128	44.0	29.7

[a]Mean and median calculations do not include nondetects.

FOD = Frequency of Detection; n/a = not applicable; U = Not detected; highest method detection limit of Aroclor for the sample is presented when no detected Aroclors.

Table 7 summarizes sediment low-molecular weight PAH (LPAH)[3] concentrations by compound and by creek/river basin; only those LPAHs detected at least once were included (see Appendix C for all LPAH data). Napthalene and acenapthylene were not detected in any sediment samples. No LPAHs were detected in Covington Creek and Green River samples. Highest frequency of detection was generally at Mill Creek in Kent. Of the LPAH compounds detected in at least one sample, acenaphthene was detected least often and phenanthrene was detected most often. The highest concentration of individual LPAH compounds were generally found in Soos Creek, but these also had the most variable LPAH concentrations.

Table 7. Green River Watershed Sediment LPAH Concentrations (µg/kg dry weight) Summary Statistics

Compound	Creek	FOD	Min	Max	Mean[a]	Median[a]
Acenaphthene	Newaukum Creek	1/10	n/a	11.2	n/a	n/a
	Covington Creek	0/7	n/a	13U	n/a	n/a
	Jenkins Creek	1/5	n/a	186	n/a	n/a
	Soos Creek	1/11	n/a	207	n/a	n/a
	Mill Creek Auburn	0/8	n/a	13U	n/a	n/a
	Mill Creek Kent	2/8	13	29.8	21	n/a
	Springbrook Creek	2/5	6.0	11	8.5	n/a
	Green River	0/4	n/a	11U	n/a	n/a
	All Sites Combined	7/58	6.0	207	66.3	13.0
Anthracene	Newaukum Creek	4/10	7.5	17.0	13	14
	Covington Creek	0/7	n/a	13U	n/a	n/a
	Jenkins Creek	2/5	25.8	52.5	39.2	n/a
	Soos Creek	4/11	4.9	461	129	25
	Mill Creek Auburn	3/8	11	14	12	12
	Mill Creek Kent	8/8	14	106	55	47.8
	Springbrook Creek	3/5	24.1	42.3	34.8	38.0
	Green River	0/4	n/a	11U	n/a	n/a
	All Sites Combined	24/58	4.9	461	51.0	25

[3] LPAHs include acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, and phenanthrene.

Compound	Creek	FOD	Min	Max	Mean[a]	Median[a]
Fluorene	Newaukum Creek	1/10	n/a	18.9	n/a	n/a
	Covington Creek	0/7	n/a	13U	n/a	n/a
	Jenkins Creek	1/5	n/a	205	n/a	n/a
	Soos Creek	1/11	n/a	205	n/a	n/a
	Mill Creek Auburn	1/8	n/a	20	n/a	n/a
	Mill Creek Kent	7/8	12	39.4	24	18
	Springbrook Creek	3/5	20.5	37.2	29.5	30.9
	Green River	0/4	n/a	11U	n/a	n/a
	All Sites Combined	14/58	12	205	50.3	25.7
Phenanthrene	Newaukum Creek	7/10	3.5	101	28.5	16.9
	Covington Creek	0/7	n/a	13U	n/a	n/a
	Jenkins Creek	4/5	20	208	86.9	59.8
	Soos Creek	8/11	3.1	994	140	10.4
	Mill Creek Auburn	7/8	43.0	94.5	65.8	58.6
	Mill Creek Kent	8/8	92.9	643	338	270
	Springbrook Creek	4/5	21	294	190	224
	Green River	0/4	n/a	11U	n/a	n/a
	All Sites Combined	38/58	3.1	994	147	59.2

[a]Mean and median calculations do not include nondetects.

FOD = Frequency of Detection. n/a = not applicable. U = Not detected; highest method detection limit of samples summarized.

Table 8 summarizes sediment high molecular weight PAH (HPAH)[4] concentrations by compound and by creek/river basin. All individual HPAHs were detected in at least one sample, but the number of HPAH compounds detected in each sample varied greatly. Green River samples had the lowest frequency of detection for all HPAHs followed by Covington and Jenkins Creek. Mill Creek in Kent had the highest frequency of detection for all HPAHs. On average, both Springbrook Creek and Mill Creek in Kent had the highest concentrations of individual HPAH compounds.

[4] HPAHs include benzo(a)anthracene, benzo (g,h,i)perylene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(b,j,k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno (1,2,3-cd)perylene, and pyrene

Table 8. Green River Watershed Sediment HPAH Concentrations (µg/kg dry weight) Summary Statistics

Compound	Creek	FOD	Min	Max	Mean[a]	Median[a]
Benzo(a)anthracene	Newaukum Creek	7/10	3.7	54.5	21.0	16.9
	Covington Creek	1/7	n/a	8.2	n/a	n/a
	Jenkins Creek	1/5	n/a	21	n/a	n/a
	Soos Creek	6/11	4.2	608	120	22.1
	Mill Creek Auburn	7/8	39.0	102	61.0	56.6
	Mill Creek Kent	8/8	95.1	790	379	328
	Springbrook Creek	3/5	185	327	278	322
	Green River	0/4	n/a	11U	n/a	n/a
	All Sites Combined	33/58	3.7	790	158	56.6
Benzo(a)pyrene	Newaukum Creek	9/10	3.5	62.9	21.0	12.7
	Covington Creek	0/7	n/a	45U	n/a	n/a
	Jenkins Creek	2/5	21	69	45	n/a
	Soos Creek	4/11	4.3	290	78.6	31.6
	Mill Creek Auburn	7/8	9.6	152	74.4	74.0
	Mill Creek Kent	8/8	122	1030	494	517
	Springbrook Creek	3/5	248	487	333	265
	Green River	0/4	n/a	11U	n/a	n/a
	All Sites Combined	34/58	3.5	1030	181	67.5
Benzo(b)fluoranthene	Newaukum Creek	8/10	4.5	93.5	29.6	16.2
	Soos Creek	7/11	3.5	292	63.8	9.82
	Springbrook Creek	3/5	435	824	606	559
	Sites Combined	18/26	3.5	824	139	22
Benzo(k)fluoranthene	Newaukum Creek	9/10	3.4	68.9	22.0	10
	Soos Creek	4/11	8.41	341	117	59.8
	Springbrook Creek	3/5	388	771	516	390
	Sites Combined	16/26	3.4	771	138	29
Benzo(b,j,k)fluoranthene	Covington Creek	6/7	14	23	18	18
	Jenkins Creek	3/5	78.6	174	130	138
	Mill Creek Auburn	8/8	23.3	424	210	201
	Mill Creek Kent	8/8	323	2830	1410	1510
	Green River	1/4	n/a	14	n/a	n/a
	Sites Combined	26/32	14	2830	518	183

Compound	Creek	FOD	Min	Max	Mean[a]	Median[a]
Benzo(g,h,i)perylene	Newaukum Creek	7/10	3.5	45.5	14	7.3
	Covington Creek	0/7	n/a	45U	n/a	n/a
	Jenkins Creek	0/5	n/a	64U	n/a	n/a
	Soos Creek	4/11	4.0	137	59.0	47.6
	Mill Creek Auburn	3/8	39.4	110	63	41
	Mill Creek Kent	8/8	71	351	220	237
	Springbrook Creek	3/5	267	537	371	310
	Green River	0/4	n/a	11U	n/a	n/a
	All Sites Combined	25/58	3.5	537	135	71
Chrysene	Newaukum Creek	9/10	4.3	86.9	26	9.6
	Covington Creek	1/7	n/a	17.9	n/a	n/a
	Jenkins Creek	3/5	47.4	91.9	75.2	86.4
	Soos Creek	8/11	3.1	731	119	12
	Mill Creek Auburn	8/8	9.2	199	98.9	103
	Mill Creek Kent	8/8	173	1240	657	654
	Springbrook Creek	3/5	335	630	531	628
	Green River	0/4	n/a	11U	n/a	n/a
	All Sites Combined	40/58	3.1	1240	227	86.7
Dibenzo(a,h)anthracene	Newaukum Creek	1/10	n/a	15.2	n/a	n/a
	Covington Creek	0/7	n/a	45U	n/a	n/a
	Jenkins Creek	0/5	n/a	64U	n/a	n/a
	Soos Creek	1/11	n/a	51.8	n/a	n/a
	Mill Creek Auburn	0/8	n/a	64U	n/a	n/a
	Mill Creek Kent	5/8	66	115	87	84
	Springbrook Creek	3/5	75.8	174	110	79.6
	Green River	0/4	n/a	11U	n/a	n/a
	All Sites Combined	10/58	15.2	174	83.2	79.8
Fluoranthene	Newaukum Creek	8/10	5.6	152	43.3	21.9
	Covington Creek	2/7	17.1	23	20	n/a
	Jenkins Creek	5/5	17	193	88.5	74.3
	Soos Creek	9/11	4.5	1010	157	17.5
	Mill Creek Auburn	8/8	15.6	265	134	128
	Mill Creek Kent	8/8	230	1950	933	800
	Springbrook Creek	3/5	372	697	554	592
	Green River	1/4	n/a	11	n/a	n/a
	All Sites Combined	44/58	4.5	1950	283	98.3

Compound	Creek	FOD	Min	Max	Mean[a]	Median[a]
Indeno(1,2,3-Cd)Pyrene	Newaukum Creek	6/10	3.5	42.2	15	9.3
	Covington Creek	0/7	n/a	45U	n/a	n/a
	Jenkins Creek	0/5	n/a	64U	n/a	n/a
	Soos Creek	1/11	n/a	123	n/a	n/a
	Mill Creek Auburn	2/8	45.7	96.0	70.9	n/a
	Mill Creek Kent	8/8	63.0	384	227	237
	Springbrook Creek	3/5	243	518	340	258
	Green River	0/4	n/a	11U	n/a	n/a
	All Sites Combined	20/58	3.5	518	160	122
Pyrene	Newaukum Creek	9/10	5.3	169	42.3	14.9
	Covington Creek	2/7	15.9	17	16	n/a
	Jenkins Creek	5/5	15	168	79	60.5
	Soos Creek	8/11	5.5	916	154	17.3
	Mill Creek Auburn	8/8	15.8	280	149	142
	Mill Creek Kent	8/8	254	2150	1170	974
	Springbrook Creek	3/5	432	877	722	856
	Green River	1/4	n/a	10	n/a	n/a
	All Sites Combined	44/58	5.3	2150	336	103

[a]Mean and median calculations do not include nondetects.

FOD = Frequency of Detection.; n/a = not applicable. U = Not detected; highest method detection limit of samples summarized.

Note: After 2010, KCEL began reporting benzo(b)fluoranthene and benzo(k)fluoranthene as benzo(b,j,k)fluoranthenes.

Table 9 summarizes sediment phthalate concentrations by compound and by creek/river basin. At least one phthalate compound was detected in every sample, but the number of phthalates detected in each sample varied greatly. Di-n-octyl phthalate had the lowest number of detections. Bis(2-ethylehexyl)phthalate was detected in the majority of the samples and had the highest detected concentrations of the phthalates. Dimethyl phthalate was the compound with the lowest detected sediment concentrations. Bis(2-ethylhexyl)phthalate was the only phthalate detected in the Green River and was only observed in one sample at a relatively low concentration compared to other detected results. With the exception of di-n-butyl phthalate and diethyl phthalate, Mill Creek in Auburn or Mill Creek in Kent had the highest maximum concentrations of phthalate compounds.

Table 9. Green River Watershed Sediment Phthalate Concentrations (µg/kg dry weight) Summary Statistics

Compound	Creek	FOD	Min	Max	Mean[a]	Median[a]
Benzyl Butyl Phthalate	Newaukum Creek	6/10	57.2	121	85.2	78.8
	Covington Creek	0/7	n/a	19U	n/a	n/a
	Jenkins Creek	1/5	n/a	34.8	n/a	n/a
	Soos Creek	2/11	14	54	34	n/a
	Mill Creek Auburn	4/8	52.9	1320	453	220
	Mill Creek Kent	8/8	75.9	460	215	172
	Springbrook Creek	4/5	70.7	178	117	110
	Green River	0/4	n/a	16U	n/a	n/a
	All Sites Combined	25/58	14	1320	185	121
Bis(2-Ethylhexyl) Phthalate	Newaukum Creek	10/10	51.7	418	123	83.9
	Covington Creek	5/7	27	50.8	42	46
	Jenkins Creek	3/5	71.1	336	216	241
	Soos Creek	11/11	8.8	203	44.1	18.4
	Mill Creek Auburn	8/8	39.4	2060	820	691
	Mill Creek Kent	8/8	1420	8010	3150	1930
	Springbrook Creek	5/5	32.6	3520	2010	2180
	Green River	1/4	n/a	20	n/a	n/a
	All Sites Combined	51/58	8.8	8010	871	101
Di-N-Butyl Phthalate	Newaukum Creek	10/10	7.7	39.0	17.9	14
	Covington Creek	0/7	n/a	26U	n/a	n/a
	Jenkins Creek	0/5	n/a	26U	n/a	n/a
	Soos Creek	8/11	12	35.0	18	16
	Mill Creek Auburn	3/8	23	51.3	36	34
	Mill Creek Kent	2/8	28	81.7	54.9	n/a
	Springbrook Creek	3/5	33.5	325	152	96.8
	Green River	0/4	n/a	22U	n/a	n/a
	All Sites Combined	26/58	7.7	325	38	20
Di-N-Octyl Phthalate	Newaukum Creek	0/10	n/a	19U	n/a	n/a
	Covington Creek	0/7	n/a	89U	n/a	n/a
	Jenkins Creek	0/5	n/a	127U	n/a	n/a
	Soos Creek	0/11	n/a	45U	n/a	n/a
	Mill Creek Auburn	1/8	n/a	252	n/a	n/a
	Mill Creek Kent	2/8	245	602	424	n/a
	Springbrook Creek	0/5	n/a	37U	n/a	n/a
	Green River	0/4	n/a	22U	n/a	n/a
	All Sites Combined	3/58	245	602	366	252

Compound	Creek	FOD	Min	Max	Mean[a]	Median[a]
Diethyl Phthalate	Newaukum Creek	5/10	6.6	16	11	12
	Covington Creek	2/7	34	49.0	42	n/a
	Jenkins Creek	2/5	64.6	328	196	n/a
	Soos Creek	0/11	n/a	45U	n/a	n/a
	Mill Creek Auburn	0/8	n/a	25U	n/a	n/a
	Mill Creek Kent	0/8	n/a	25U	n/a	n/a
	Springbrook Creek	1/5	n/a	86.1	n/a	n/a
	Green River	0/4	n/a	22U	n/a	n/a
	All Sites Combined	10/58	6.6	328	61.6	25
Dimethyl Phthalate	Newaukum Creek	0/10	n/a	19U	n/a	n/a
	Covington Creek	0/7	n/a	26U	n/a	n/a
	Jenkins Creek	1/5	n/a	34.9	n/a	n/a
	Soos Creek	0/11	n/a	45U	n/a	n/a
	Mill Creek Auburn	2/8	135	159	147	n/a
	Mill Creek Kent	2/8	29.7	45.0	37.4	n/a
	Springbrook Creek	2/5	49.3	55.9	52.6	n/a
	Green River	0/4	n/a	22U	n/a	n/a
	All Sites Combined	7/58	29.7	159	72.7	49.3

[a]Mean and median calculations do not include nondetects.

FOD = Frequency of Detection. U = Not detected; highest method detection limit of samples summarized.
n/a = not applicable

Table 10 summarizes dioxin TEQ concentrations for each location sampled. Dioxin TEQ concentrations were highest in Springbrook Creek followed by Mill Creek in Kent. Lowest concentrations were found at the sites in the Green River followed by Soos Creek. Map 5 illustrates the spatial distribution of dioxin TEQ concentrations. This map is intended to provide spatial context for the concentration of dioxins, which are key contaminants of concern for the Lower Duwamish Waterway based on human health risks.

Table 10. Green River Watershed Sediment Dixoin TEQ Concentrations (ng TEQ/kg dry weight) and Summary Statistics

Creek	Station Locator	Dioxin TEQ Concentration
Green River at Flaming Geyser	FG319	0.18
Newaukum Creek	X322	6.50
Soos Creek	0320	0.64
Mill Creek in Auburn	A315	2.21
Mill Creek in Kent	IT318	16.2
Springbrook Creek	0317	20.5
Green River at Foster Links	FL319	0.12
	Mean	**6.62**
	Median	**2.21**

Table 11 summarizes grain size distribution of the sediment samples. Sediment consisted of 50% or more sand particle sizes on average for all locations with the exception of Jenkins Creek where sediment consisted of nearly 50% fine particles on average. The Green River locations had the highest fraction of sands with mean of 83.8% sand. Fines tended to have more silt than clay except at Mill Creek in Auburn, Covington Creek, and Jenkins Creek where silt and clay fraction were similar.

Table 11. Green River Watershed Sediment Grain Size Summary Statistics (% Composition)

Creek	Grain Size	Min	Max	Mean	Median
Newaukum Creek n=10	Fines:	2.9	46.5	24.3	24.0
	Clay	7.3	13.9	10.6	10.6
	Silt	2.9	37.1	22.2	24.0
	Sand	42.9	80.5	60.6	63.6
	Gravel	0.9	42.0	14.7	10.0
Covington Creek n=7	Fines:	3.1	16.9	9.7	10.4
	Clay	2.4	9.6	5.3	5.0
	Silt	0.6	10.3	4.4	2.2
	Sand	28.8	83.1	56.6	63.2
	Gravel	7.7	70.0	32.6	27.4
Jenkins Creek n=5	Fines:	21.9	69.6	49.8	50.2
	Clay	8.8	30.9	23.7	27.4
	Silt	13.2	41.0	26.1	22.8
	Sand	19.8	49.1	34.6	34.7
	Gravel	2.1	44.2	19.0	14.8

Creek	Grain Size	Min	Max	Mean	Median
Soos Creek n=11	Fines:	2.0	49.6	17.3	11.6
	Clay	0.7	24.8	6.1	4.0
	Silt	1.4	27.5	11.8	8.1
	Sand	46.7	87.8	68.2	65.7
	Gravel	0.7	48.9	18.0	12.9
Mill Creek Auburn n=8	Fines:	2.6	51.1	23.3	18.8
	Clay	1.9	28.7	12.2	7.35
	Silt	0.6	26.3	11	7.6
	Sand	38.9	92.6	54.3	48.2
	Gravel	6.8	57.2	22.7	15.2
Mill Creek Kent n=8	Fines:	9.4	61.0	33.7	32.0
	Clay	5.2	23.3	12.9	12.2
	Silt	4.2	45.2	20.8	18.4
	Sand	35.1	70.2	53.0	52.2
	Gravel	0.3	32.9	10	3.0
Springbrook Creek n=5	Fines:	18.2	64.7	38.4	33.8
	Clay	8.4	30.2	18.0	14.9
	Silt	3.3	34.5	20.4	25.3
	Sand	22.4	72.7	48.1	50.9
	Gravel	4.5	9.8	6.7	5.9
Green River n=4	Fines:	2.4	21.6	9.9	7.8
	Clay	2.4	7.6	4.4	3.9
	Silt	3.0	14.0	7.3	4.8
	Sand	67.5	90.3	83.8	88.7
	Gravel	0.4	12.2	7.3	9.4
All Sites Combined n=58	Fines:	2.0	69.6	24.9	21.6
	Clay	0.6	45.2	15.7	11.9
	Silt	0.7	30.9	11.3	8.1
	Sand	19.8	92.6	57.9	59.5
	Gravel	0.3	70.0	17.2	11.3

n = sample number

Table 12 summarizes sediment TOC. Median TOC ranged from 0.75 % in Green River sediment to 13.3 % in Jenkins Creek sediment. Green River sediment had the least variable TOC while the most variable TOC was found in Soos Creek sediment.

Table 12. Green River Watershed Total Organic Carbon Summary Statistics (% dry weight)

Creek	Min	Max	Mean	Median
Newaukum Creek	0.92%	8.20%	3.22%	2.66%
Jenkins Creek	11.2%	16.8%	13.4%	13.3%
Covington Creek	0.89%	12.5%	4.79%	3.96%
Soos Creek	0.41%	16.8%	3.79%	2.43%
Mill Creek Auburn	0.96%	12.3%	3.75%	2.18%
Mill Creek Kent	1.71%	6.29%	3.83%	3.57%
Springbrook Creek	2.95%	11.3%	6.64%	5.32%
Green River	0.51%	1.04%	0.76%	0.75%
All Sites Combined	0.41%	16.8%	4.68%	3.56%

5.2 Data Validation

Metals, organics and conventional data from samples collected in 2012 were validated by King County using EPA National Functional Guidelines for Superfund data (EPA 2008 and 2010) and the study SAP.[5] Details of this validation are described in a data validation technical memorandum provided in Appendix D. Validation of dioxin/furan congener data was completed by Laboratory Data Consultants, Inc. in accordance with EPA Superfund guidance (EPA 2009). Dioxin/furan congener validation reports are also provided in Appendix D. This section summarizes the major findings of the chemistry data validations.

5.2.1 Metals, Organics, and Conventionals

KCEL reviewed the metals, organics and conventional parameter data by comparing the results to reference methods and SAP requirements, and flagging data with laboratory qualifiers where appropriate. Validation of these data was conducted by Water and Land Resources Division Science Unit staff. Materials reviewed for this data validation included Batch Reports and Analytical Quality Control (QC) Reports downloaded from the King County Laboratory Information System database, along with data anomaly forms. The QC parameters reviewed during this data validation include; holding time, method blanks, spike blanks, matrix spikes, matrix spike duplicates, laboratory control samples, standard reference materials, check standards, 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. Data

[5] Data quality reviews for the 2008-2010 sediment data are presented in the King County Laboratory Quality Assurance Reviews presented in Appendix A.

validation did not result in rejecting any data. Based on the information reviewed, all data are of acceptable quality. Issues that resulted in the qualification of data are summarized below.

Silt from the sample collected at station PR315 in Mill Creek in Auburn was qualified with a "J" (estimate) for relative standard deviation result outside of QC limits. Acid volatile sulfides was qualified with a "J" in the samples collected at stations TS315 and SH318 due to low matrix spike recoveries. Arsenic in the sample collected at station PR315 was qualified with a "J" for low matrix spike recoveries. Lead at station PR315 was qualified with a "J" for high matrix spike recoveries and high spike duplicate recoveries. Copper, chromium, and nickel were qualified with a "J" at station PT320 for low matrix spike recoveries. Bis(2-ethylhexyl)phthalate was qualified with a "U" in seven samples due to blank contamination. All 2,4 dimethylphenol results were qualified with a "UJ" due to low spike blank recoveries. Phenol and 2-methylphenol in several samples were flagged with a "UJ" due to low spike blank recoveries. All detected results for coprostanol and 4-nonylphenol were flagged with a "J" due to low matrix spike and spike blank recoveries. A subset of results for aldrin was qualified with a "UJ" due to low spike blank recoveries.

5.2.2 Dioxin/Furans

Dioxin/furan sediment data were validated to Level III by Laboratory Data Consultants. 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.

Instrument performance fell within method specifications except for a few instances. All of the results for 2,3,7,8-TCDF on column DB-5 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 samples. Therefore, this performance issue did not result in unusable data for this compound; results from the second column were used. All samples were analyzed as one batch; method blanks were below method performance criteria for this workgroup.

Across the whole workgroup of seven samples, 11 dioxin/furan congeners were qualified by the analytical laboratory as "K" which means that not all identification and qualification criteria were met for these compounds. The maximum potential concentration was reported for "K" 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.

6 DISCUSSION

This section provides a comparison of sediment data to the Sediment Management Standards benthic chemical criteria, the SEM/AVS ratio analysis, and compares the sediment chemistry between stream basins and the Green River main stem locations.

6.1 Comparisons to Sediment Quality Guidelines

Sediment Management Standards freshwater benthic chemical criteria are available for 25 of the 71 chemicals[6] analyzed in stream sediment samples during this survey. Of the 58 samples analyzed, 24 exceeded at least one SCO but none exceeded a CSL. Mill Creek in Kent exceeded at least one SCO chemical criterion in every sample. Springbrook Creek exceeded at least one SCO in four of five samples while Mill Creek in Auburn exceeded at least one SCO in five of eight samples. Soos Creek exceeded at least one SCO in five of eleven samples and Covington Creek exceeded at least one SCO in one of seven samples whereas Jenkins, Newaukum, and the Green River did not exceed SCOs in any sample. One station, M317, on Springbrook Creek, had the most chemical exceedances at one location (five chemicals). However, most stations with an exceedance only had one or two chemical exceedances.

Among the 58 samples, a total of six different chemicals exceeded its SCO. Bis(2-ethylhexyl)phthalate exceeded the SCO most often, exceeding sixteen times. Arsenic exceeded thirteen times, nickel exceeded seven times, cadmium exceeded four times, di-n-octyl phthalate[7] exceeded three times, and total PCBs exceeded twice. Spatial results of sediment concentrations compared to sediment quality guidelines are shown in Maps 6 through 13. The maps indicate each chemical that exceeds its SCO at each station.

6.2 SEM/AVS Ratios

SEM/AVS ratios provide information on bioavailability of metals to aquatic biota, such as benthic organisms. If metals are bioavailable, they can result in exposure but toxicity depends on exceeding a toxicity threshold, such as the CSL. Therefore, the SEM/AVS ratio provides information about bioavailability but not toxicity. SEM/AVS calculations and results are presented in Appendix B.

In Mill Creek in Auburn, arsenic exceeded the SCO at stations TS315 and ED315. However, the SEM/AVS ratios suggest that metals, including arsenic, are not bioavailable at these stations. Both arsenic and nickel exceeded the SCO at station UH315. The SEM/AVS ratio also suggests that metals are not bioavailable at this station. Nickel exceeded the SCO at station PR315 and arsenic exceeded the SCO at station FR315. At both stations the SEM/AVS ratio suggests that metals are bioavailable.

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[6] PCB Aroclors and PAH compounds are included in the Sediment Management Standards as total PCB and total PAH sums, respectively.

[7] The MDL for di-n-octyl phthalate, which was not detected, exceeded at one location.

In Mill Creek in Kent, arsenic exceeded the SCO at stations DT318 and IT318 and cadmium at station IT318. The SEM/AVS ratios suggest that metals are bioavailable at these stations.

In Springbrook Creek, arsenic and cadmium exceeded the SCO at stations K317, L317, and M317. In addition, nickel exceeded the SCO at M317. SEM/AVS ratios suggest that metals are bioavailable at stations, K317 and M317, but not at L317. Nickel exceeded the SCO at N317 and arsenic exceeded at O317; however, the SEM/AVS ratios suggest that metals are not bioavailable at these stations.

In Soos Creek, nickel exceeded the SCO at stations O320, A320 and AA320, and arsenic exceeded the SCO at GG320, HH320, and Q320. SEM/AVS ratios suggest that metals are bioavailable at all of these stations.

In Covington Creek, arsenic exceeded the SCO at station PT320. The SEM/AVS ratio suggests that metals are not bioavailable at this station.

6.3 Relative Comparison of Sediment Chemical Concentrations between Locations

This section includes a comparison of chemicals by location. Chemicals discussed in this section were selected based on high frequencies of detection within chemical groupings. For figures in this section, locations are arranged roughly upstream to downstream, SCO levels are included where applicable and basin averages, based on detected concentrations only, are shown when there were three or more detections. Figures illustrating metal concentrations include letters indicating statistical difference between basins. The stream basins vary in numbers of samples (e.g., four to ten) and therefore it is unknown if statistical differences would change if more samples were available to characterize a basin with smaller sample sizes (i.e., Green River main stem, Jenkins Creek, and Springbrook Creek). When comparing basins it is useful to note the basins of Springbrook Creek, Mill Creek in Kent, and most of Mill Creek in Auburn are more highly developed and Newaukum, Covington, and Jenkins Creeks have the least development (see Map 2).

6.3.1 Stream Basins and Green River Main Stem Locations

Metal concentrations in sediment are depicted by basin in Figures 1 through 9. Even with low sample size, there were some significant differences in metal concentration between basins.

The highest mean arsenic concentration was found in Springbrook Creek but concentrations were only significantly higher than Covington Creek (Figure 1). The highest mean cadmium concentration was in Springbrook Creek followed by Mill Creek in Kent. Cadmium concentrations in Springbrook Creek were significantly higher than Newaukum, Covington and Soos Creeks and Green River main stem sites. Mill Creek in Kent was significantly higher than Covington and Soos Creeks and Green River main stem sites (Figure 2). Springbrook Creek also had the highest mean chromium concentration and was significantly higher than all sites except Mill Creek in Kent (Figure 3). Mean copper concentrations were highest in Springbrook Creek and Mill Creek in Kent but concentrations were only significantly higher than Covington and Soos Creeks (Figure 4).

Lead similarly had the highest mean concentrations in Springbrook and Mill Creek in Kent, but these were only significantly higher than Covington and Newaukum Creeks and Green River main stem sites (Figure 5). Mercury was the only metal to show no differences between any basins (Figure 6). The highest mean nickel concentration was found in Springbrook Creek but concentrations were only found to be significantly higher than Jenkins Creek (Figure 7). Silver had highest mean concentrations in Springbrook Creek followed by Mill Creek in Kent. Silver concentrations in Springbrook Creek were significantly higher than Covington, Soos and Green River main stem sites; silver in Mill Creek in Kent was also significantly higher than Covington Creek (Figure 8). Lastly, zinc had the highest mean concentrations in Springbrook and Mill Creek in Kent but these were only significantly higher than Covington and Soos Creeks and Green River main stem sites (Figure 9).

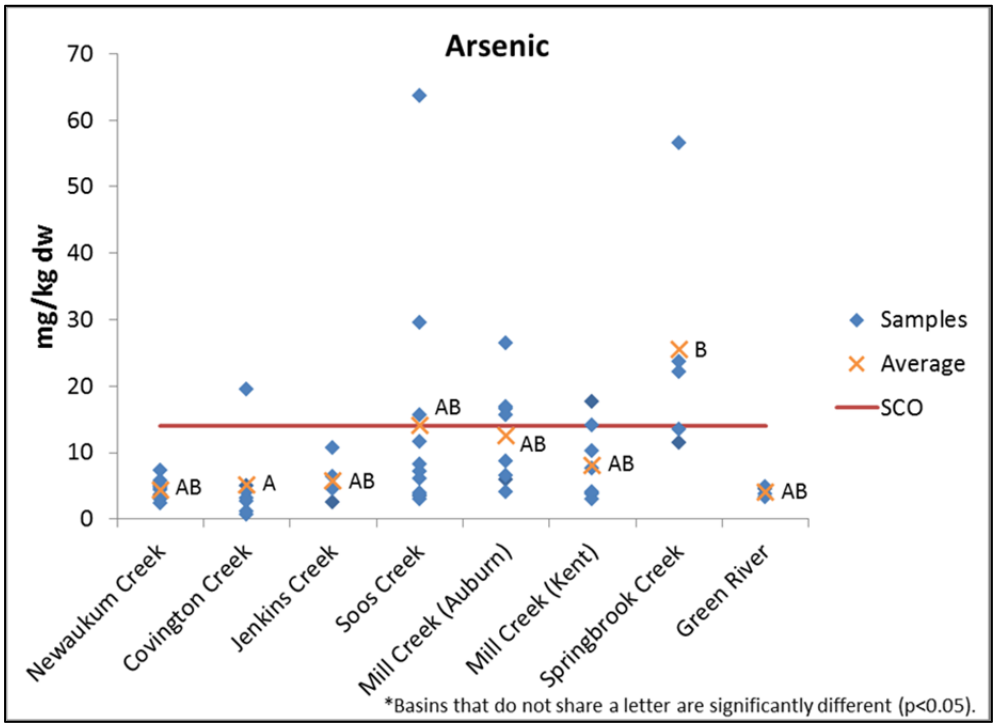

Figure 1. Arsenic Concentrations by Location

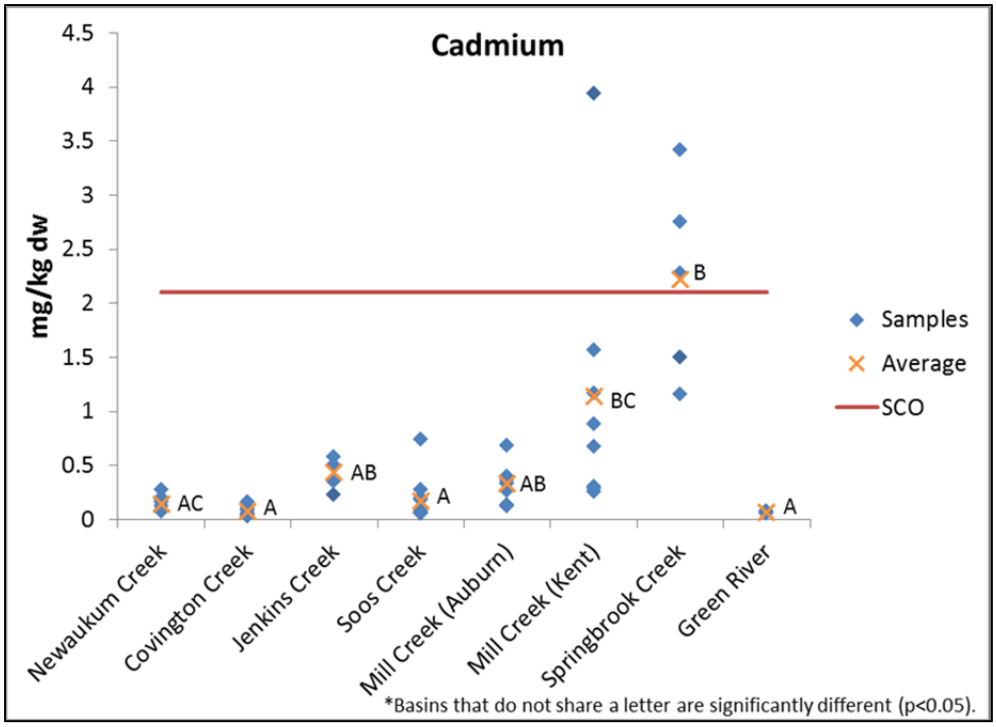

Figure 2. Cadmium Concentrations by Location

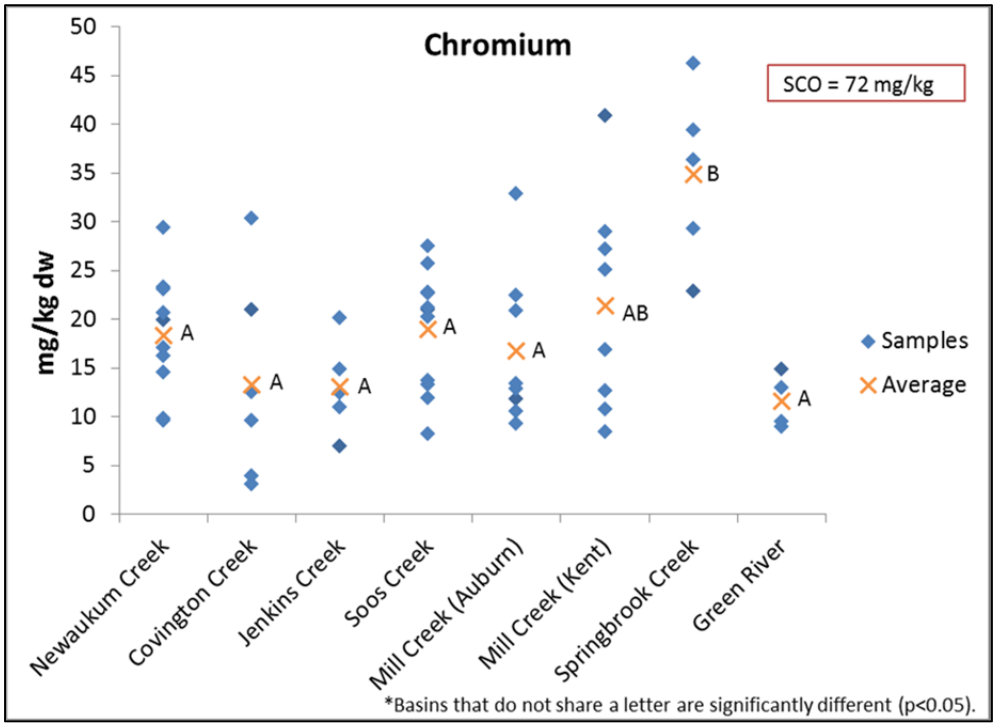

Figure 3. Chromium Concentrations by Location

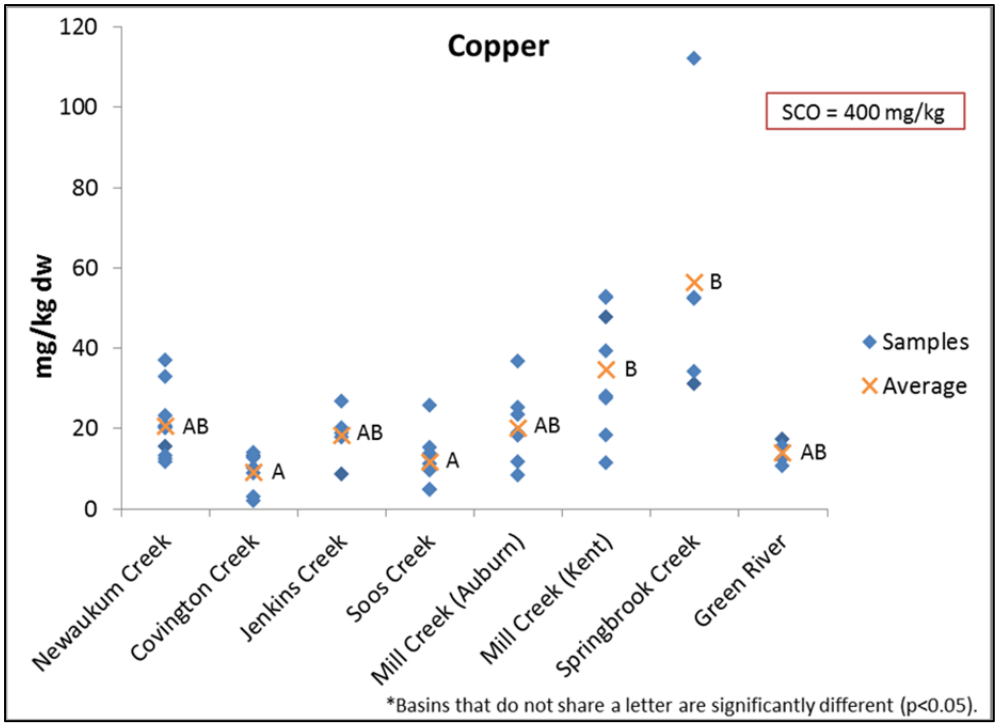

Figure 4. Copper Concentrations by Location

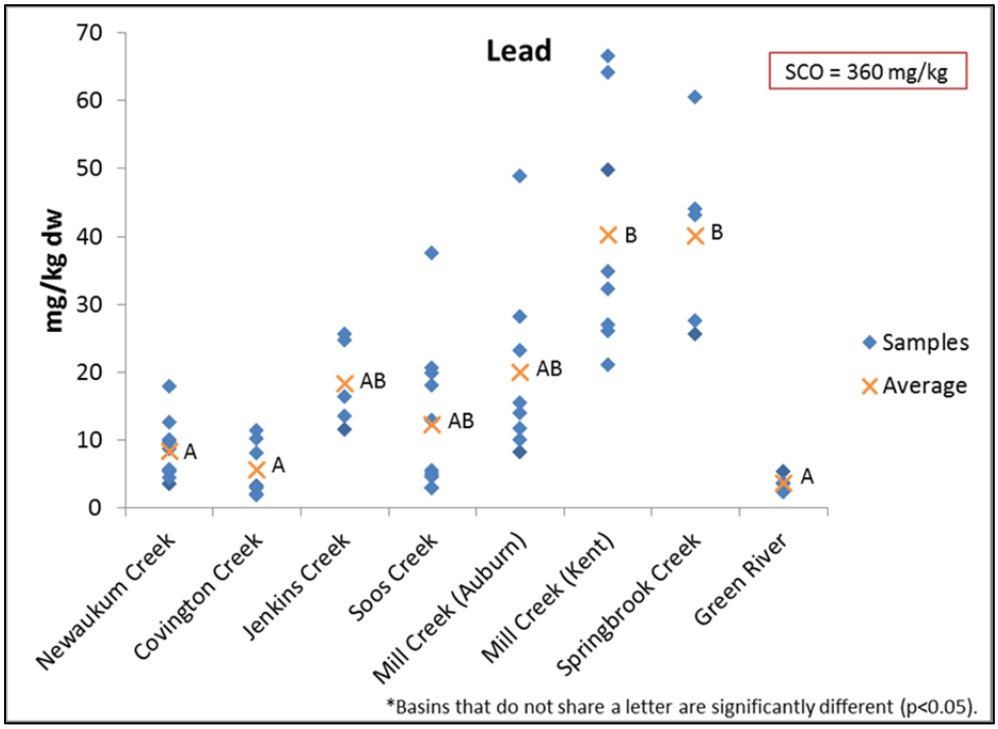

Figure 5. Lead Concentrations by Location

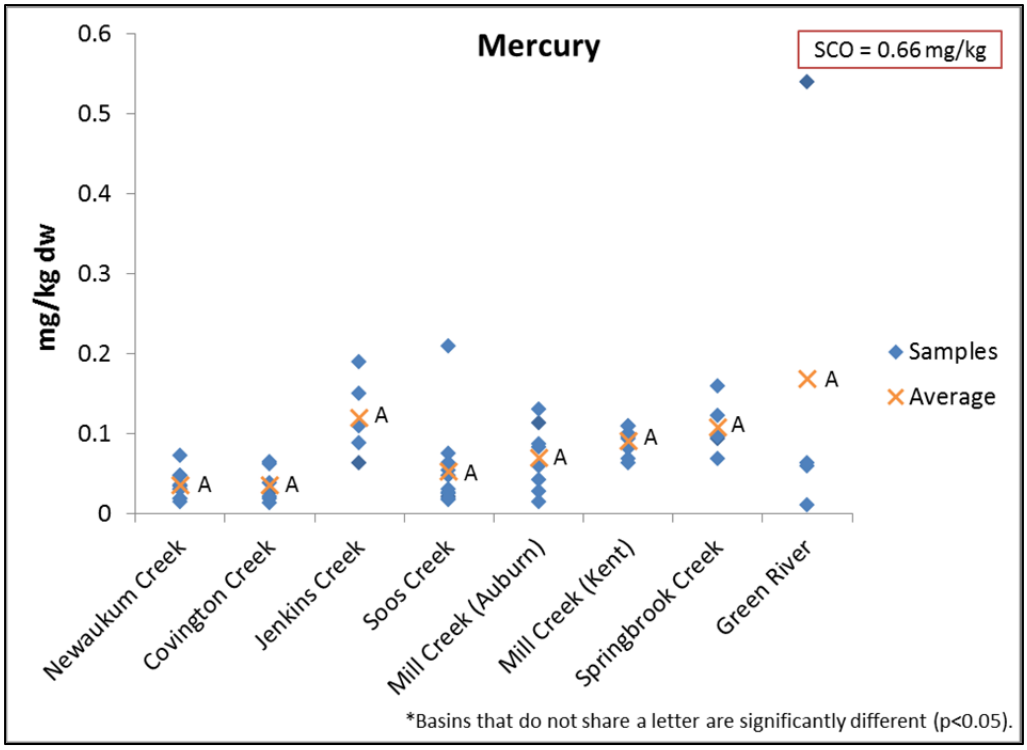

Figure 6. Mercury Concentrations by Location

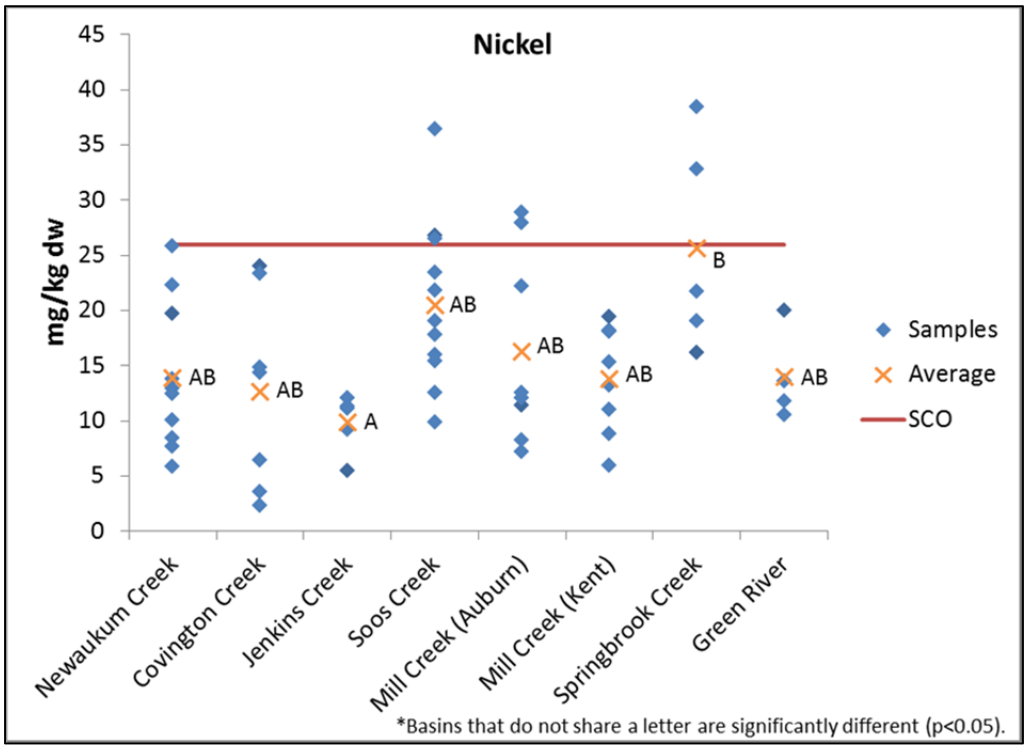

Figure 7. Nickel Concentrations by Location

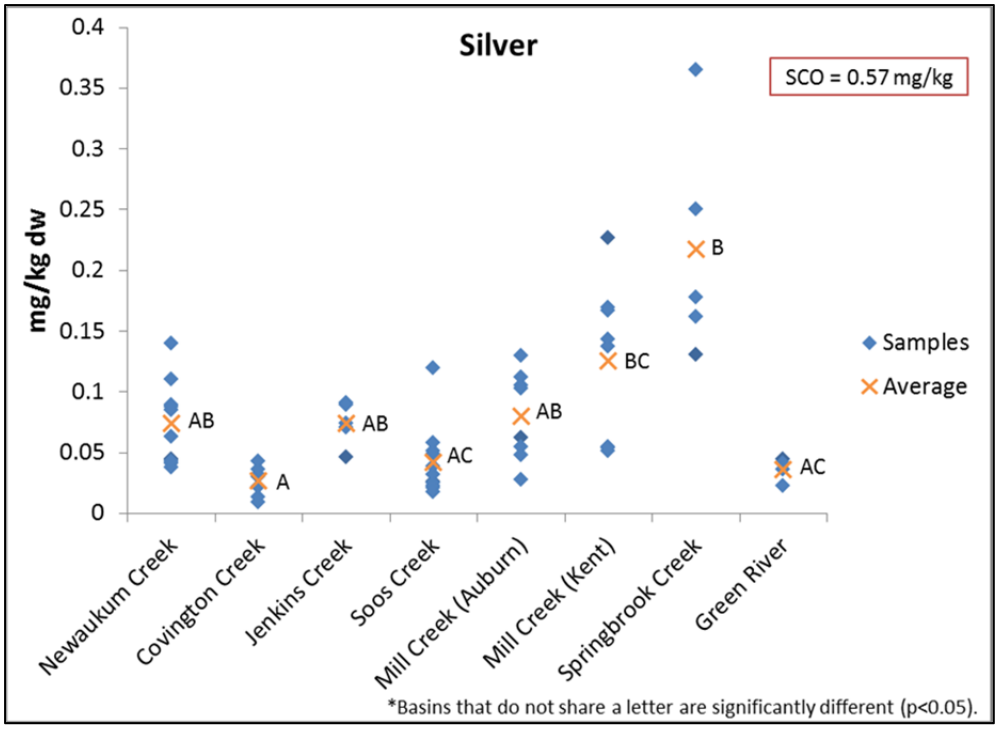

Figure 8. Silver Concentrations by Location

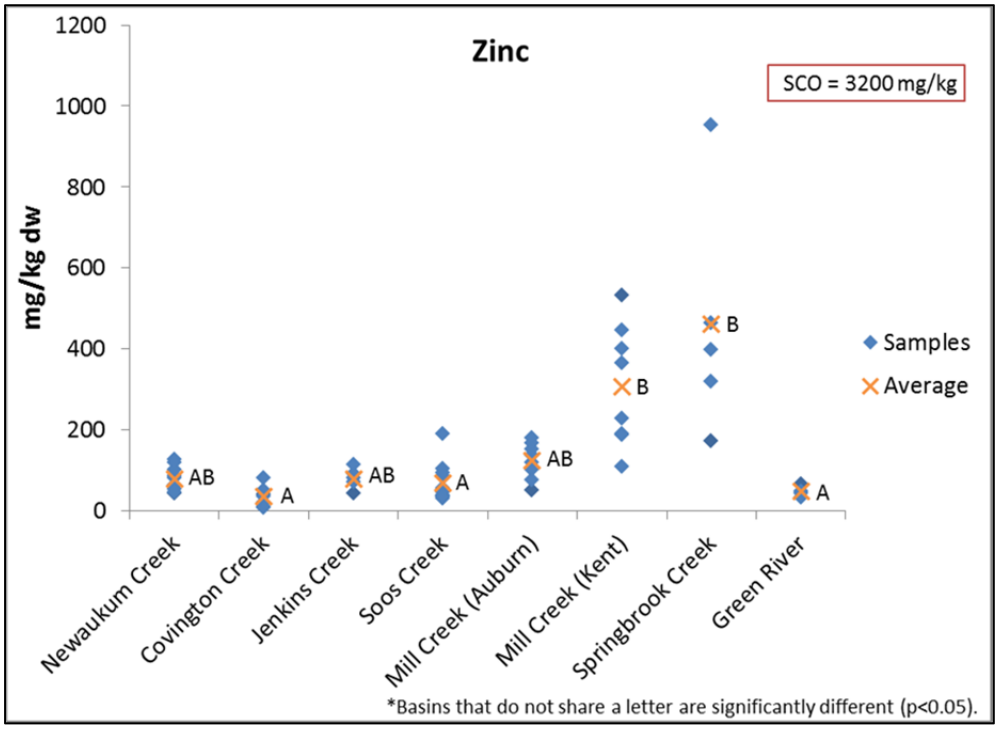

Figure 9. Zinc Concentrations by Location

Sediment concentrations of organics with the highest overall frequency of detection are depicted by basin in Figures 10 through 16. PCBs were frequently detected in samples collected in Mill Creek in Kent, Mill Creek in Auburn, and Springbrook Creek, but were rarely or not detected in the remaining stream basins and Green River main stem sites (Figure 10). Seven of the eight highest concentrations were detected in Springbrook Creek and Mill Creek in Kent.

LPAHs with the highest frequencies of detection were anthracene and phenanthrene. The highest concentration of anthracene was observed in Soos Creek with the next three highest concentrations in Mill Creek in Kent (Figure 11). Phenanthrene was frequently detected in all basins except Covington Creek and the Green River main stem sites, both of which had no detections. Of the twelve highest phenanthrene concentrations, seven were observed in Mill Creek in Kent, three in Springbrook Creek and one in Soos Creek basin (Figure 12).

HPAHs with the highest frequencies of detection were chrysene, fluoranthene and pyrene[8]. For all three compounds, the eleven highest concentrations were found in Mill Creek in Kent (seven), Springbrook Creek (three) and Soos Creek (one) (Figures 13 through 15).

Bis(2-ethylhexyl)phthalate was the most frequently detected phthalate across all stream basins; the Green River main stem sites had the fewest detections. The thirteen highest concentrations were detected in Mill Creek in Kent (eight), Springbrook Creek (three) and Mill Creek in Auburn (two) (Figure 16).

[8] Benzo(b)fluoranthene and benzo(k)fluoranthene were also frequently detected at Newaukum, Soos and Springbrook Creeks. Benzo(b,j,k)fluoranthene was frequently detected at Covington, Jenkins, Mill (Kent) and Mill (Auburn) Creeks. However, they were not graphed or included in this analysis because different ways this compound was reported between 2008-2010 and 2012 samples (see Table 8).

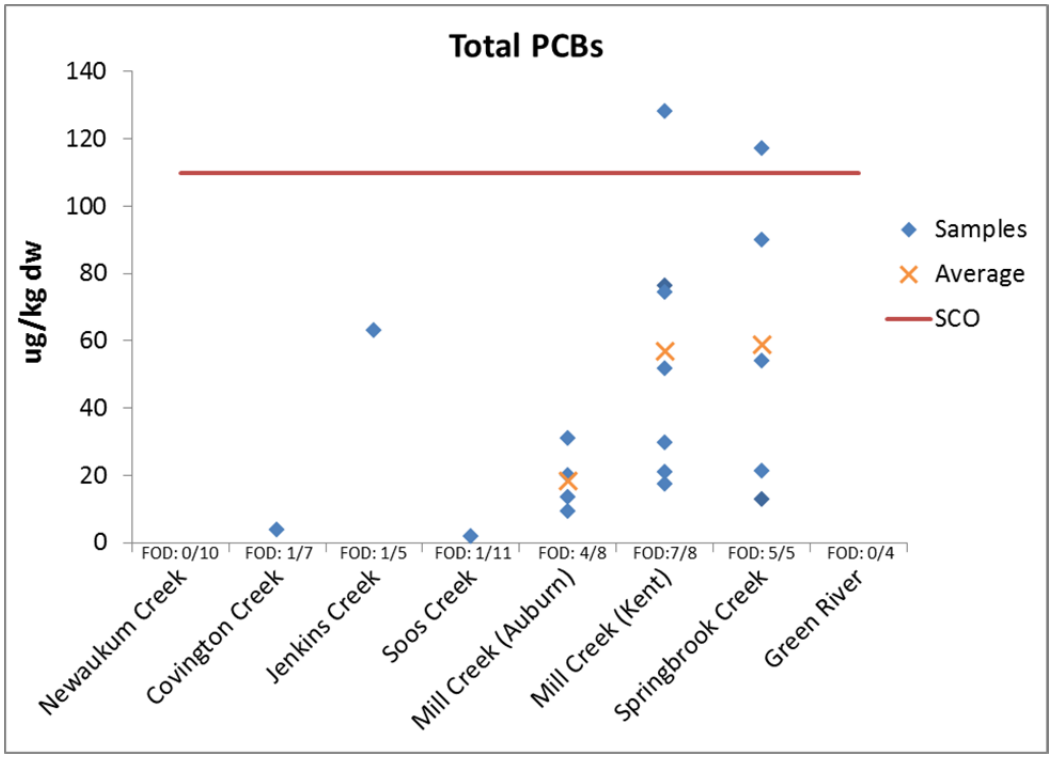

Figure 10. Detected Total PCB Concentrations by Location

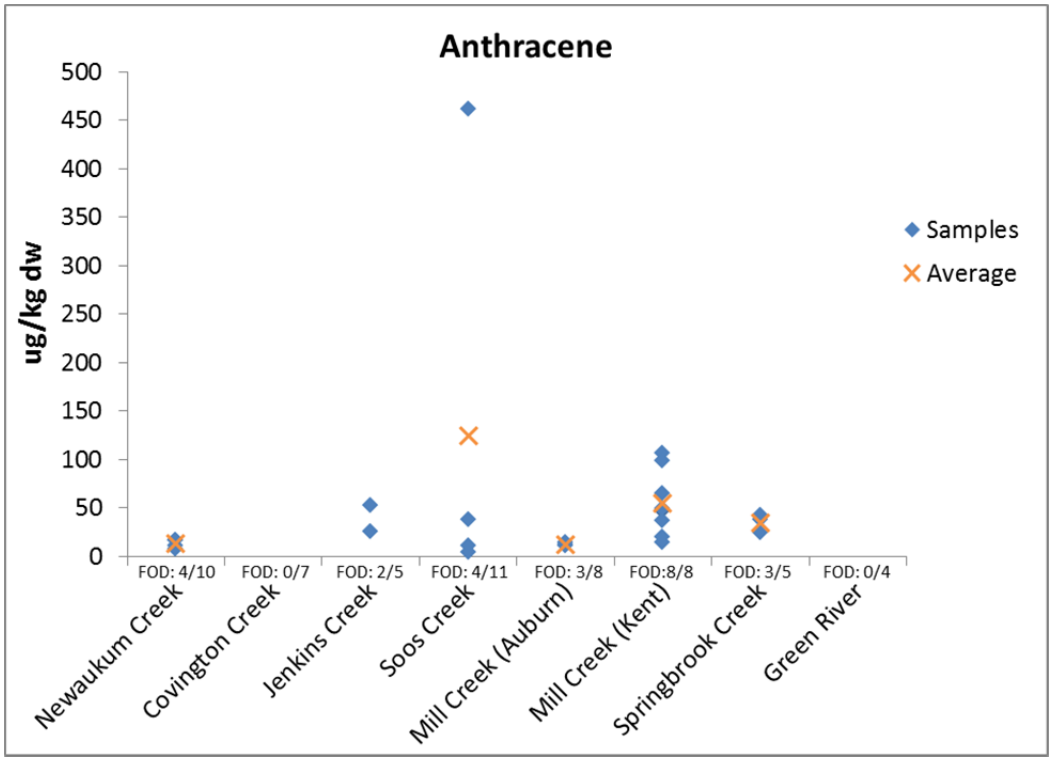

Figure 11. Detected Anthracene Concentrations by Location

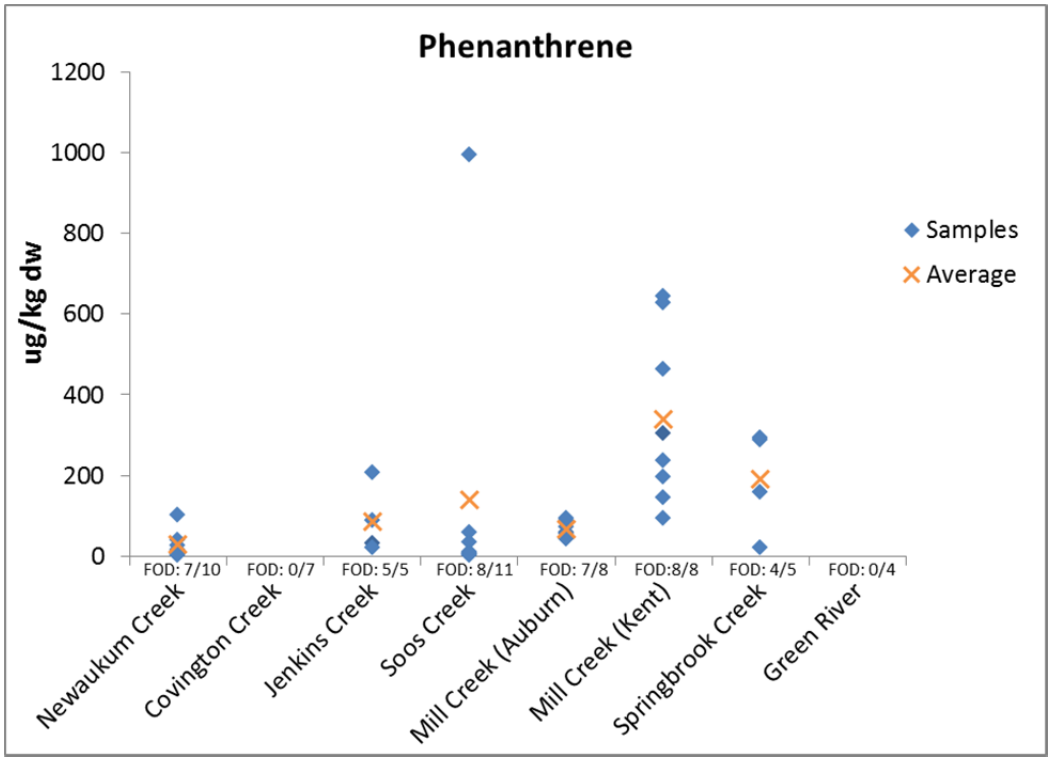

Figure 12. Detected Phenanthrene Concentrations by Location

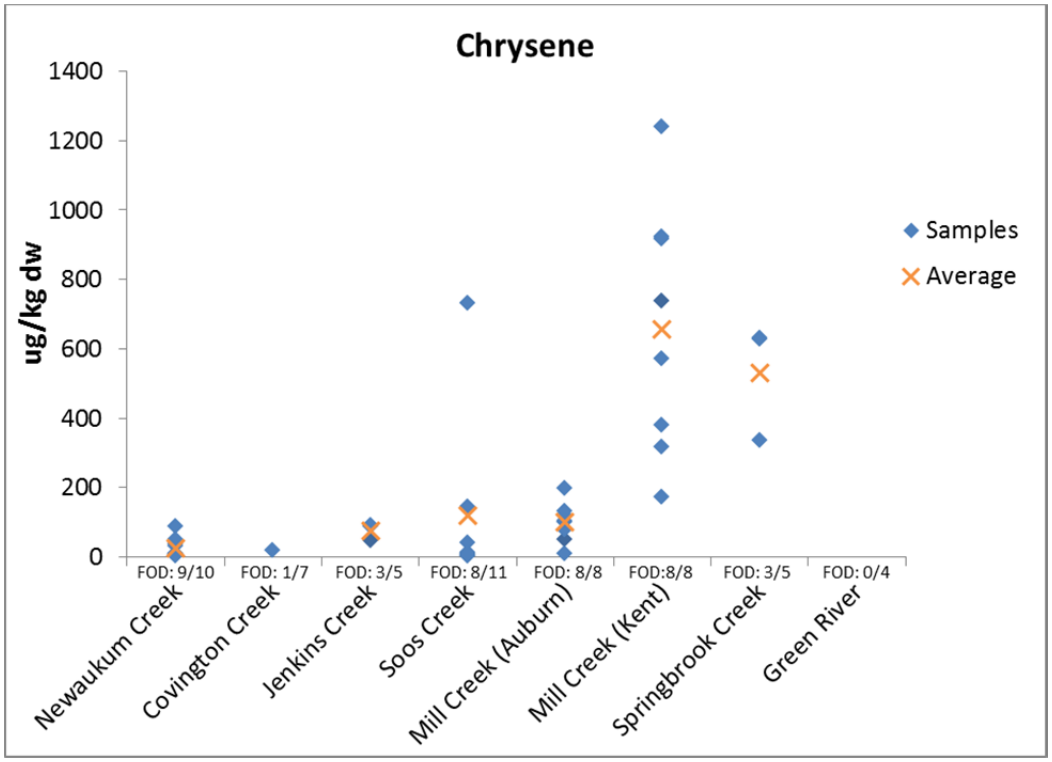

Figure 13. Detected Chrysene Concentrations by Location

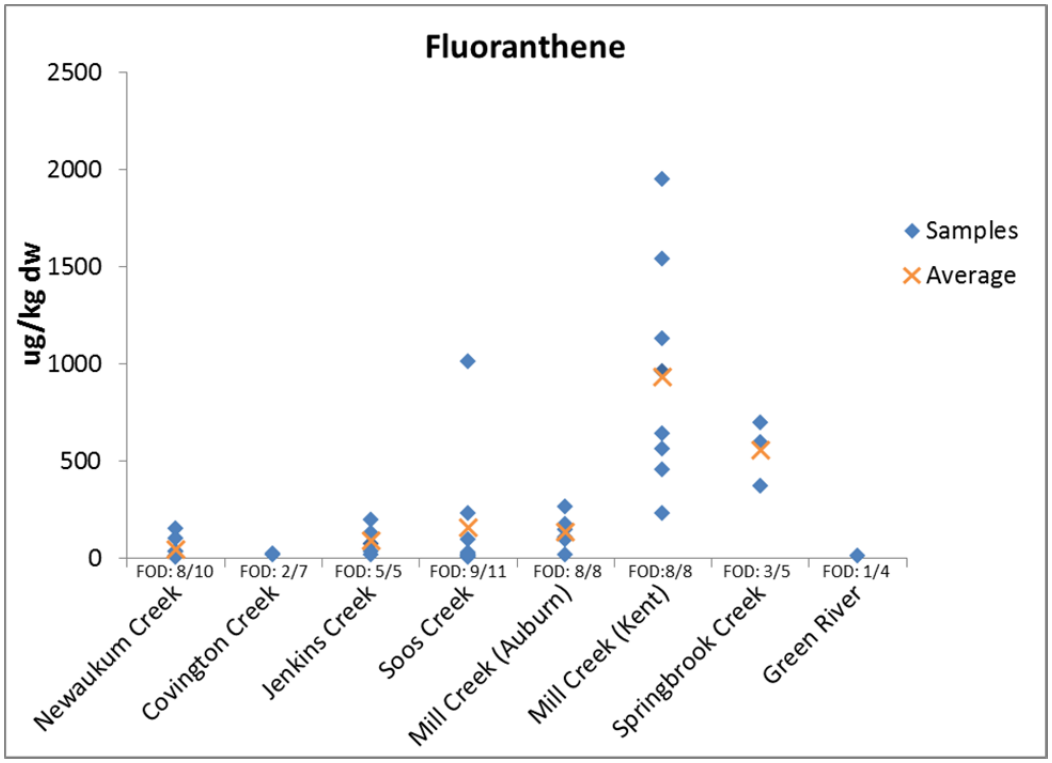

Figure 14. Detected Fluoranthene Concentrations by Location

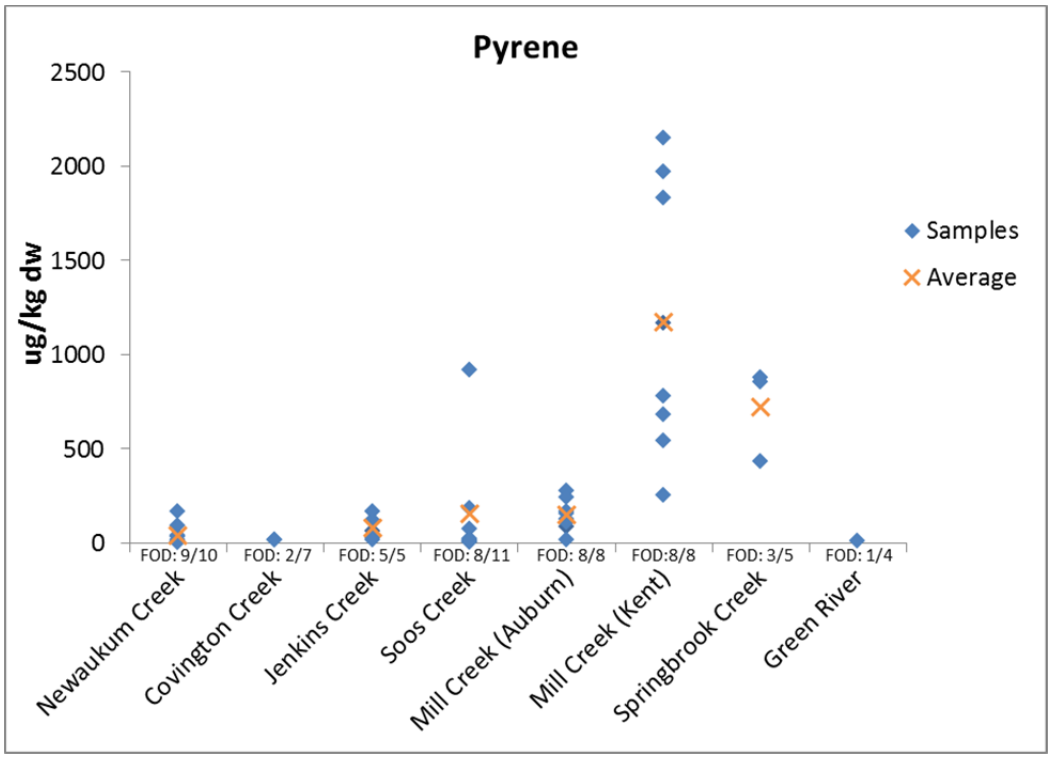

Figure 15. Detected Pyrene Concentrations by Location

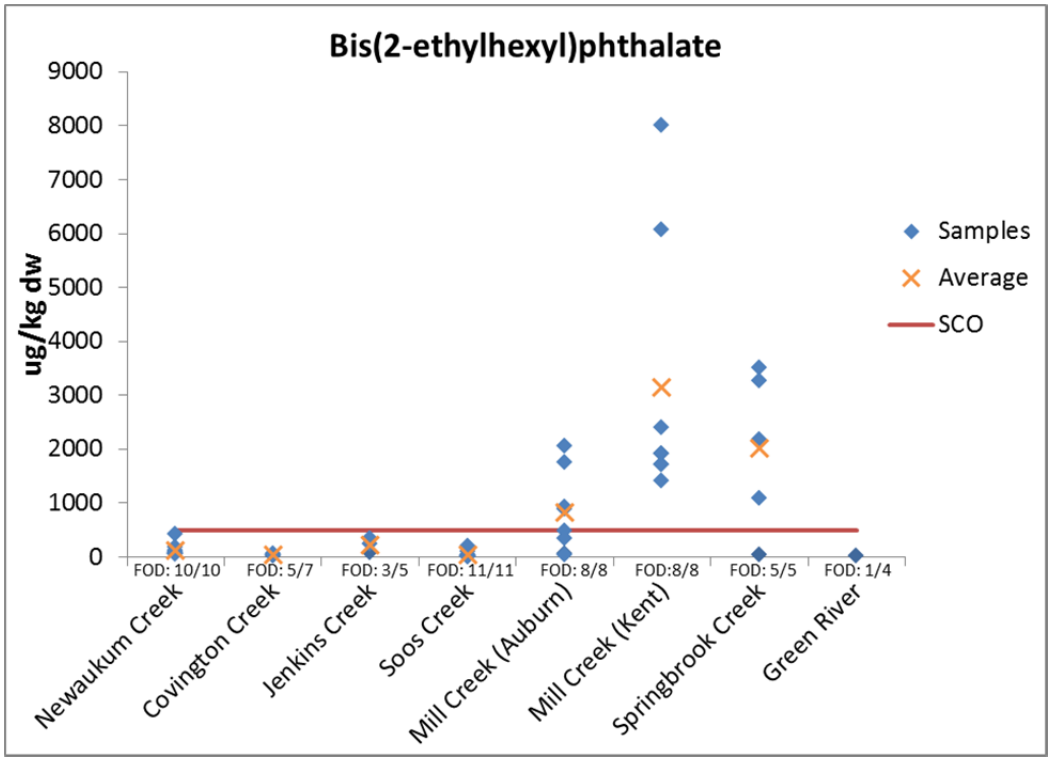

Figure 16. Detected Bis(2-ethylhexyl)phthalate Concentrations by Location

6.3.2 Green River Main Stem Sites

This section presents a comparison of sediment chemistry results between Green River main stem sampling sites. Figure 17 illustrates metal concentrations at each main stem site. With the exception of arsenic, the highest concentrations of metals in the Green River main stem were found at the second most upstream site (A319). This site also had the highest percentage of fines. With the exception of mercury, metal concentrations at all four Green River main stem sites ranged within a factor of two of each other. Only five organic compounds were detected in Green River main stem sites; these are illustrated in Figure 18, which also show non-detected values at their respective MDLs. Three HPAH compounds and coprostanol were detected at the second most downstream site (0318) and bis(2-ethylhexyl)phthalate was detected at the furthest downstream site (FL319). Detected values were within a factor of two of their respective MDLs. Overall, this analysis suggests very little difference between the Green River main stem sites.

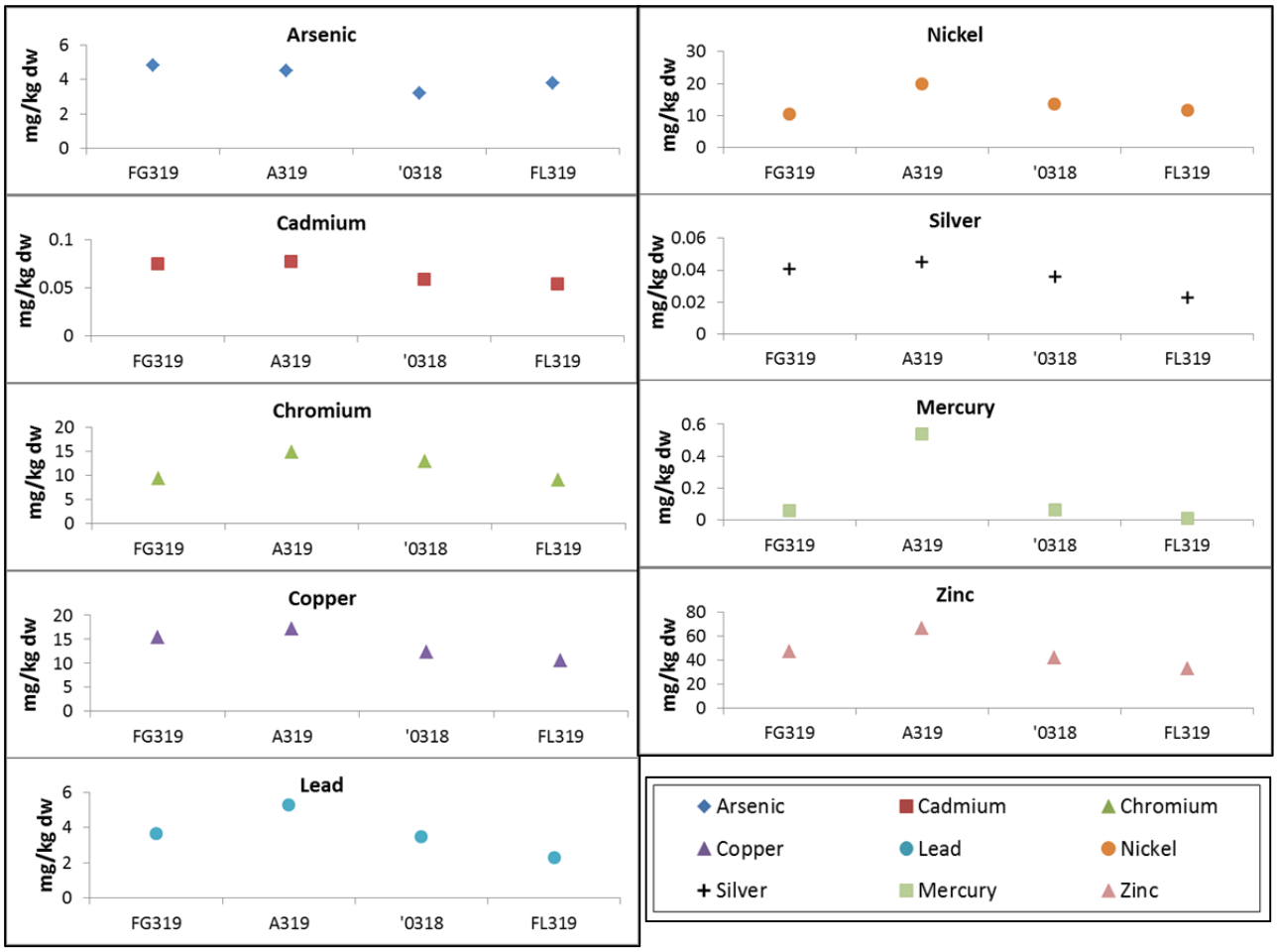

Figure 17. Concentrations of Metals at Green River Main Stem Sites

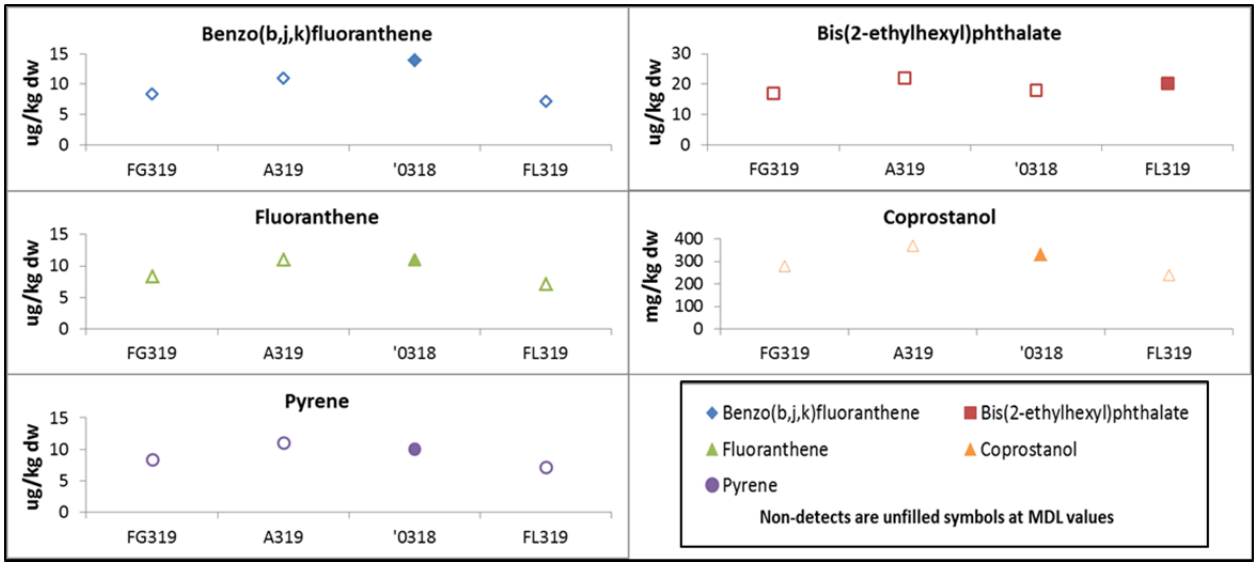

Figure 18. Concentrations of Detected Organics at Green River Main Stem Sites

Figure 19 illustrates the particle size distribution for the Green River main stem sites. The second most upstream site (A319) has the highest percentage of fines; this site had the highest concentration of most metals.

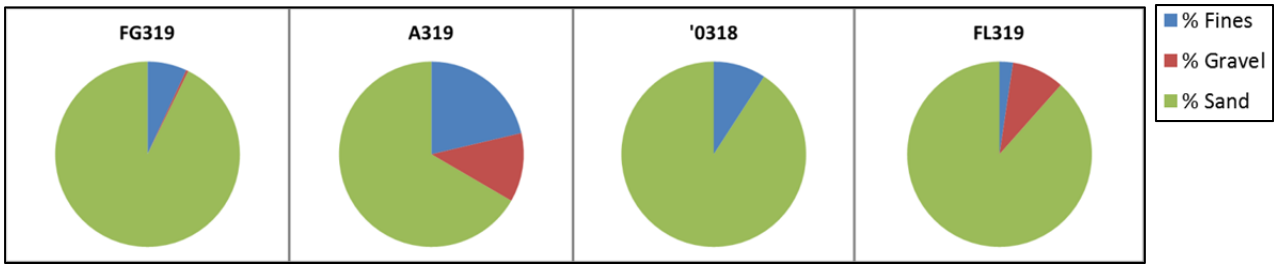

Figure 19. Particle Size Distribution for Green River Main Stem Samples

7 CONCLUSIONS

King County is conducting studies to evaluate chemical concentrations in water, sediment and suspended solids in the Green River Watershed and in atmospheric deposition within the Green/Duwamish River Watershed that may contribute chemical inputs to the LDW. The major findings of the stream sediment study are presented below.

Metals were detected at all stream basins and Green River main stem sampling locations; however, many organic compounds were infrequently or never detected. Comparisons to Washington State Sediment Management Standards for freshwater benthic (sediment-dwelling) organisms show all chemicals analyzed are below the CSL, when there is a benthic standard available for a chemical. Concentrations above the CSL would be expected to result in minor adverse effects to benthic organisms. Twenty-four of 58 samples had at least one chemical concentration above the SCO, where adverse effects are uncertain for benthic organisms. Most SCO exceedances occurred at Mill Creek in Kent, followed by Springbrook Creek, then Mill Creek in Auburn. In samples with metals concentrations above the SCO, SEM/AVS ratios indicated that metals were not bioavailable at about half the sampling locations. At locations where metals were not bioavailable they would not be expected to cause adverse effects.

Relative differences between stream tributary basins as well as the Green River main stem locations shows the more urbanized basins—Springbrook Creek, Mill Creek in Kent and to a lesser extent Mill Creek in Auburn—generally had higher concentrations of metals and organics and more exceedances of the benthic SCO standards compared to less developed tributary basins and the Green River main stem locations. The following provide supporting details for this conclusion:

- For most metals, Springbrook Creek followed by Mill Creek in Kent had the highest mean concentrations; however, significant differences in metal concentrations were not always observed between basins. SCO exceedances for arsenic and nickel occurred at many sites, while exceedances for cadmium occurred only at Springbrook Creek and at one location in Mill Creek in Kent.
- PCBs were detected most often in Springbrook Creek, Mill Creek in Kent, and Mill Creek in Auburn. PCBs were rarely or not detected in the remaining stream basins and Green River main stem sites. The highest concentrations were detected in Springbrook Creek and Mill Creek in Kent. The only two SCO exceedances were found in Mill Creek in Kent and Springbrook Creek.
- LPAHs with the highest frequencies of detection were anthracene and phenanthrene and were most frequently detected in Mill Creek in Kent. The highest concentrations of individual LPAHs were observed at one Soos Creek location; Mill Creek in Kent had the next three highest concentrations of anthracene and phenanthrene.
- HPAHs with the highest frequencies of detection were chrysene, fluoranthene and pyrene. These HPAH compounds were most frequently detected in Mill Creek in Kent and the eleven highest concentrations were found in Mill Creek in Kent (seven), Springbrook Creek (three) and Soos Creek (one).

- Most phthalates were infrequently detected with the exception of bis(2-ethylhexyl)phthalate, which was detected in the majority of the samples. The thirteen highest concentrations of bis (2-ethylhexyl)phthalate were found in Mill Creek in Kent (eight), Springbrook Creek (three) and Mill Creek in Auburn (two). These sites also had the only SCO exceedances for bis(2-ethylhexyl)phthalate.
- Dioxin/furan samples from the mouths of Springbrook and Mill Creek in Kent had the highest concentrations and Green River locations had the lowest concentrations.
- Comparison of chemical concentrations between Green River main stem sites suggests very little difference between sites. With the exception of mercury, metal concentrations at the four Green River main stem sites were within a factor of two of each other. The five organic compounds detected in Green River main stem sites were within a factor of two of their respective detection limits; other organic compounds were not detected.

On average, sediment samples consisted of 50% or more sand particle sizes for all locations with the exception of Jenkins Creek where sediment samples consisted of nearly 50% fine particles. Samples from the Green River locations generally had the lowest TOC and highest percent sand while samples from Jenkins Creek had the highest TOC and highest percent fines. Samples containing higher percentage of sand and lower TOC tend to have lower chemical concentrations.

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Maps

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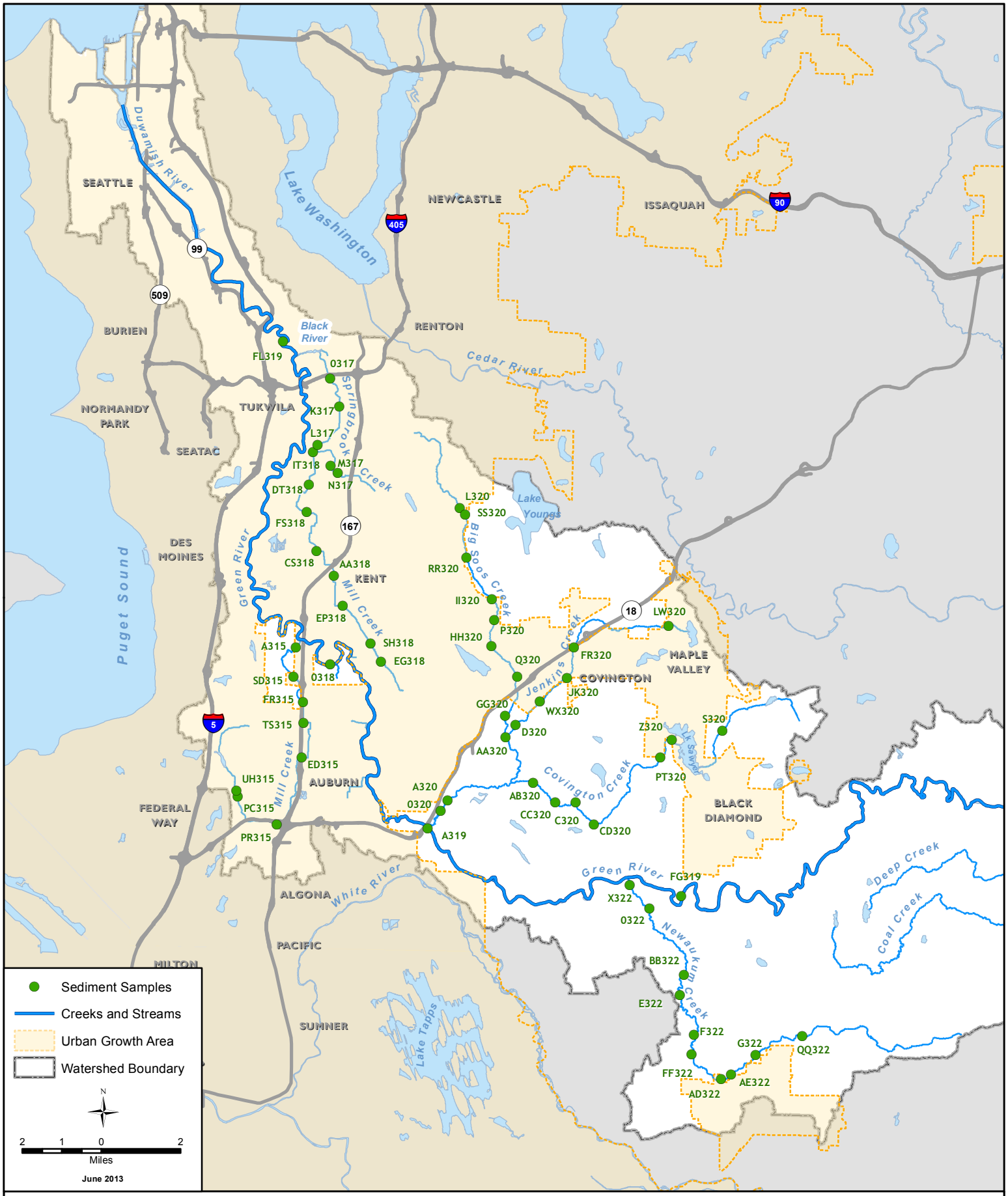

Sediment Samples

Creeks and Streams

Urban Growth Area

Watershed Boundary

N

2 1 0 2

Miles

June 2013

King County

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Map 1

Sediment Sampling Locations

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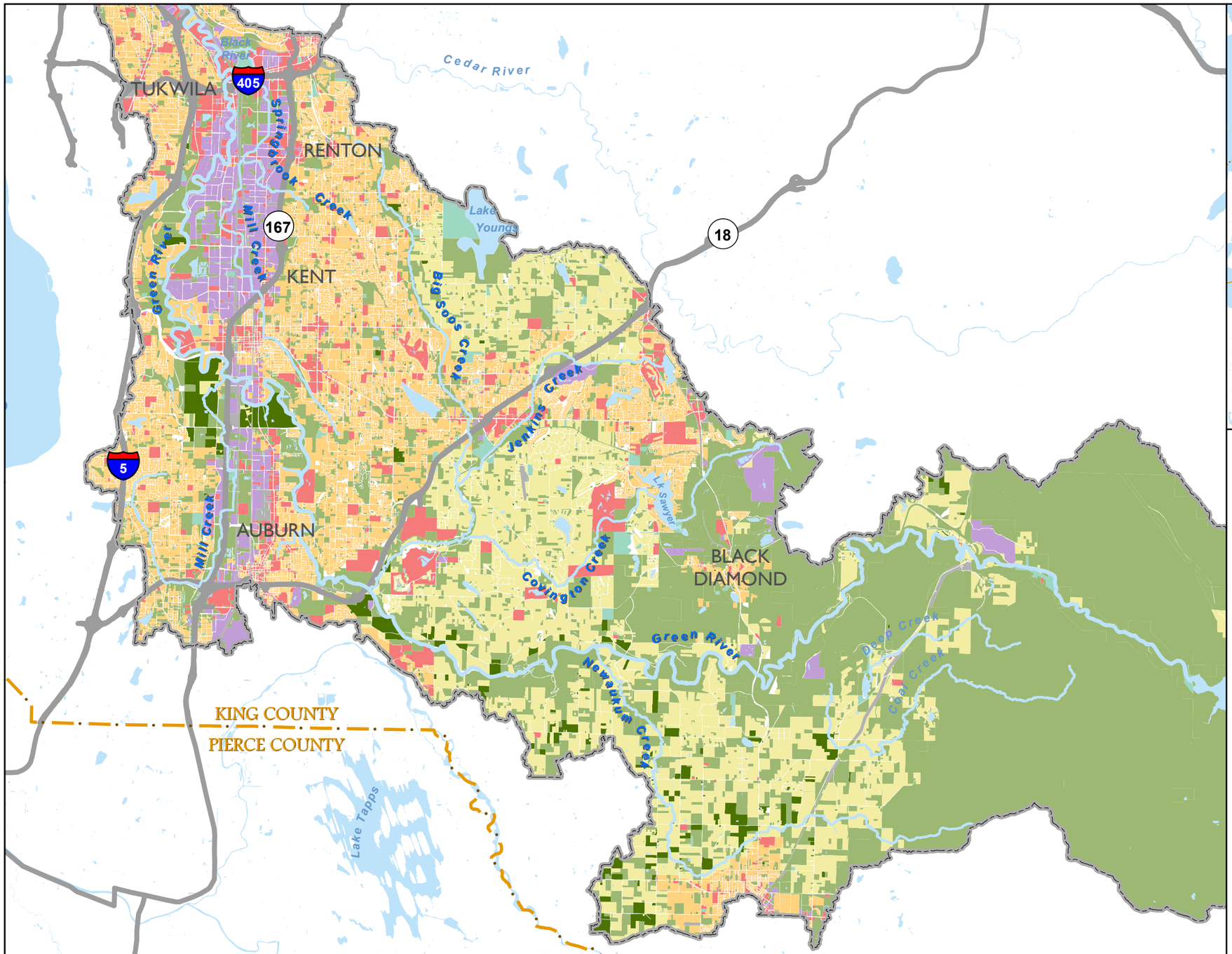

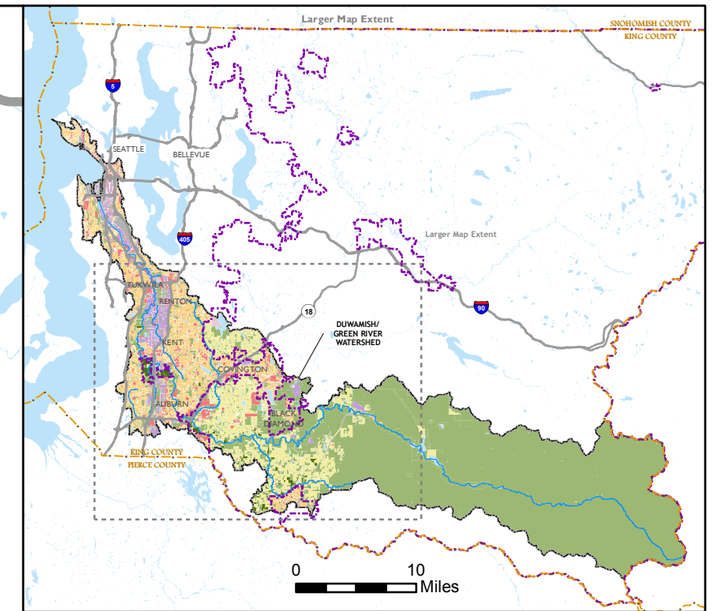

Duwamish - Green River Basin

Creeks and Streams

County Line

Urban Growth Boundary (see Inset Map)

Creeks and Streams

Freeways

Land Use Category

- Agriculture
- Commercial
- Industrial/Manufacturing
- Transportation
- Residential - Rural
- Residential - Urban
- Natural Resource/Park/Open Space
- Misc (Including Utilities, Communications)

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File Name: \\dnrp1\projects\wtd\projects\greenduwamish\projects\2013sedimentreport/LandUse10_v3.mxd
Shaun O'Neil 20130919

*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.

1.5 0.75 0 1.5
Miles

September 2013

N

Map 2

Land Use In The Green/Duwamish Watershed

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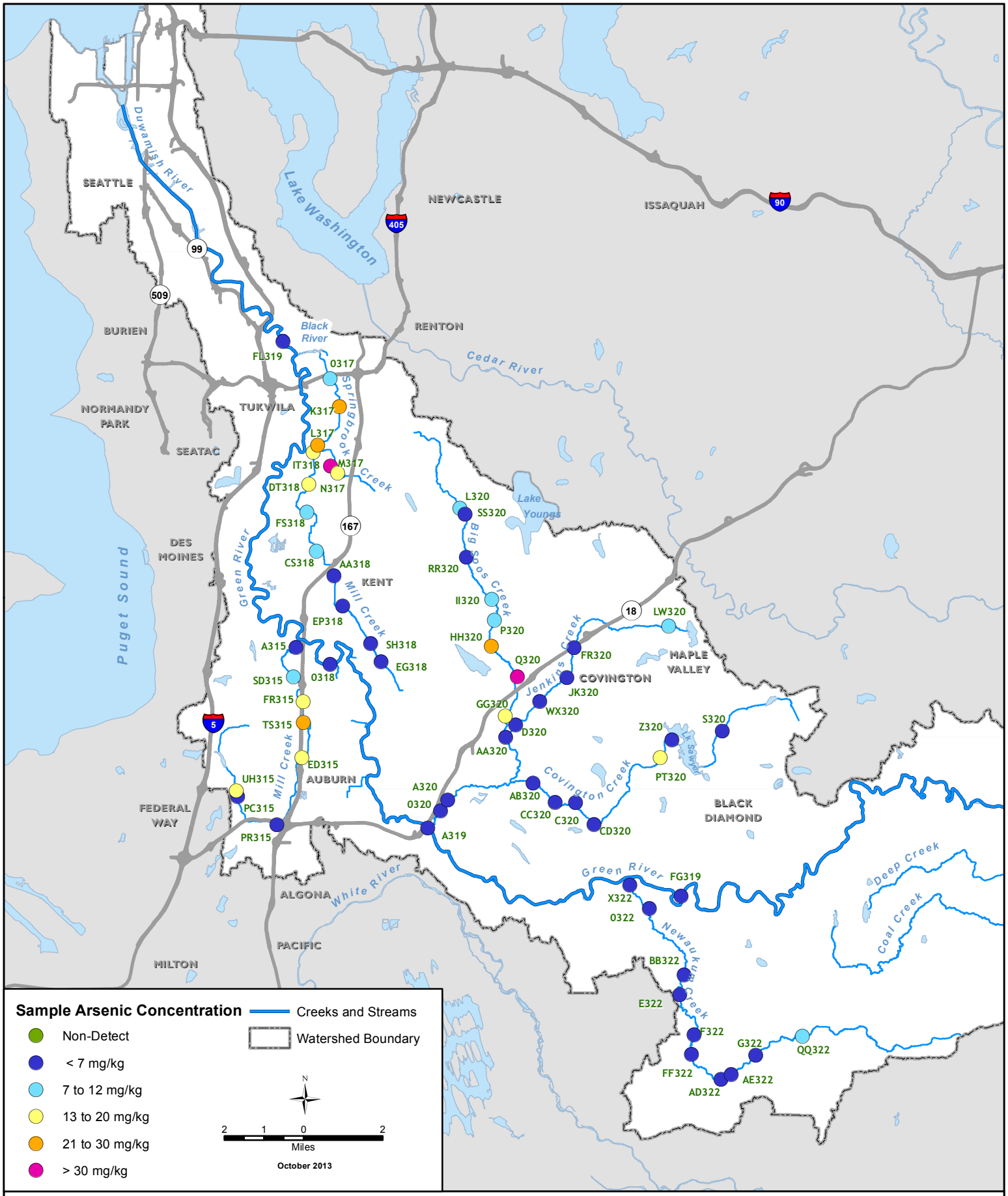

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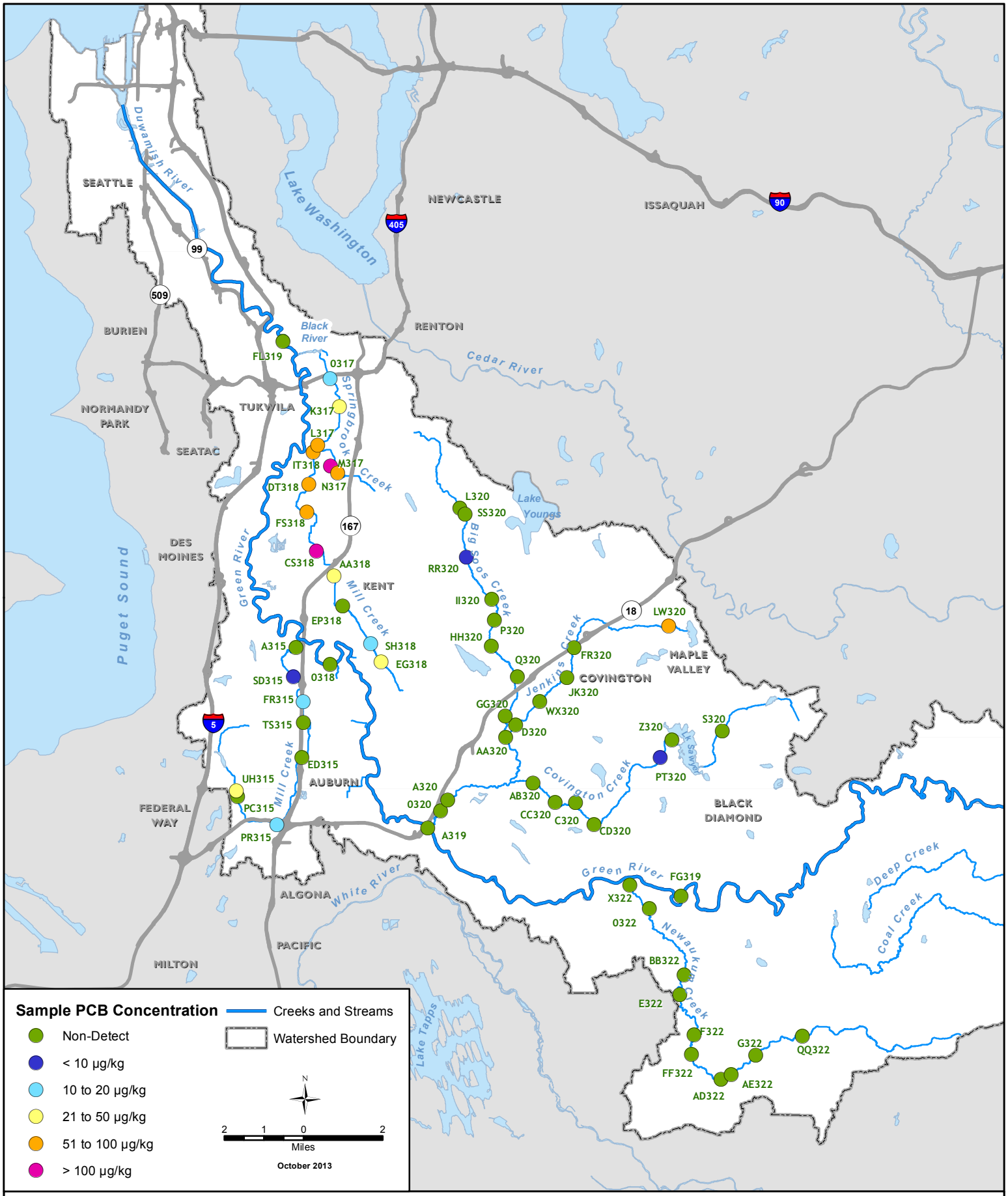
Map 3

Spatial Distribution of Arsenic concentrations



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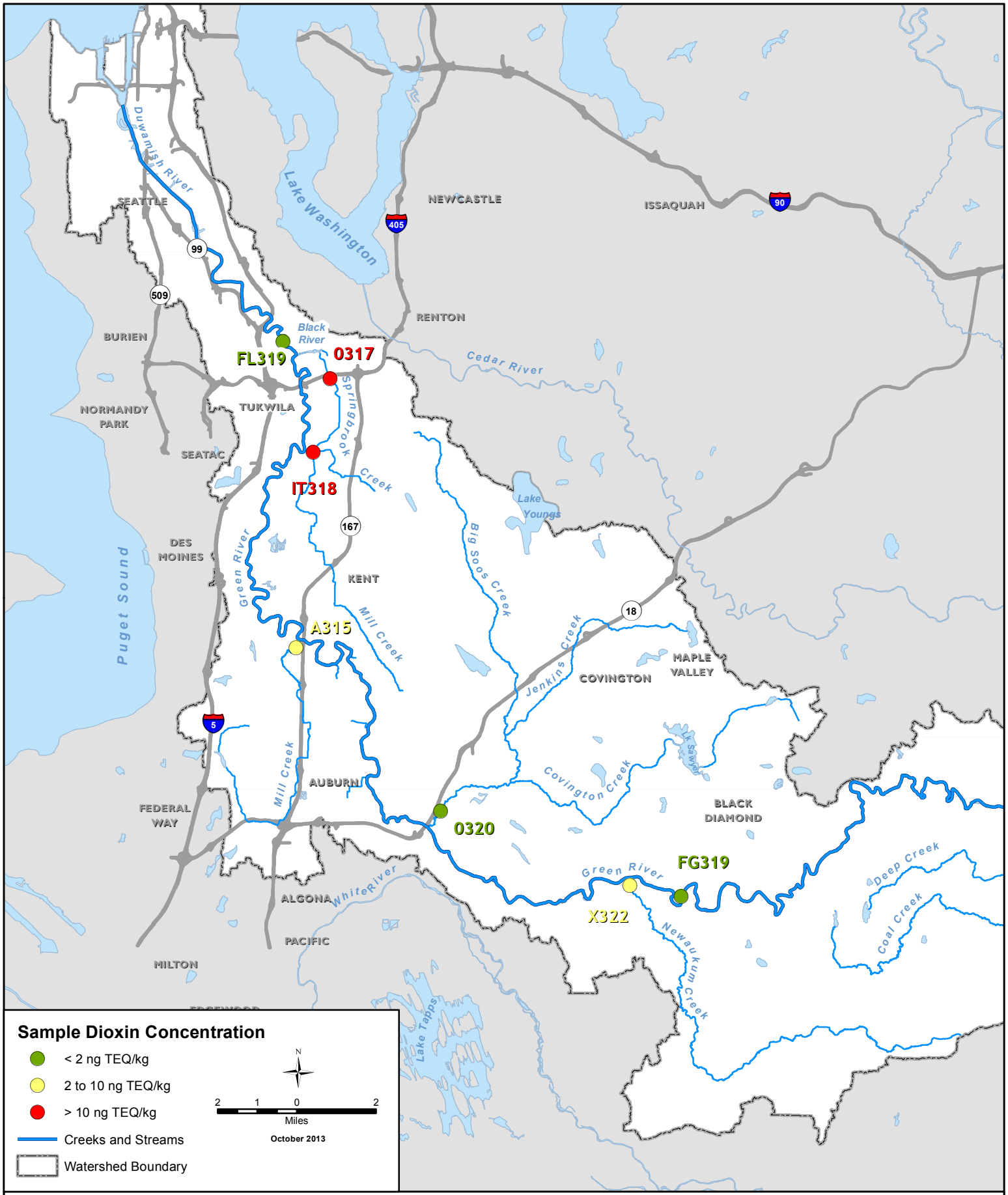
Map 4

Spatial Distribution of Total PCB Concentrations (based on Aroclors)



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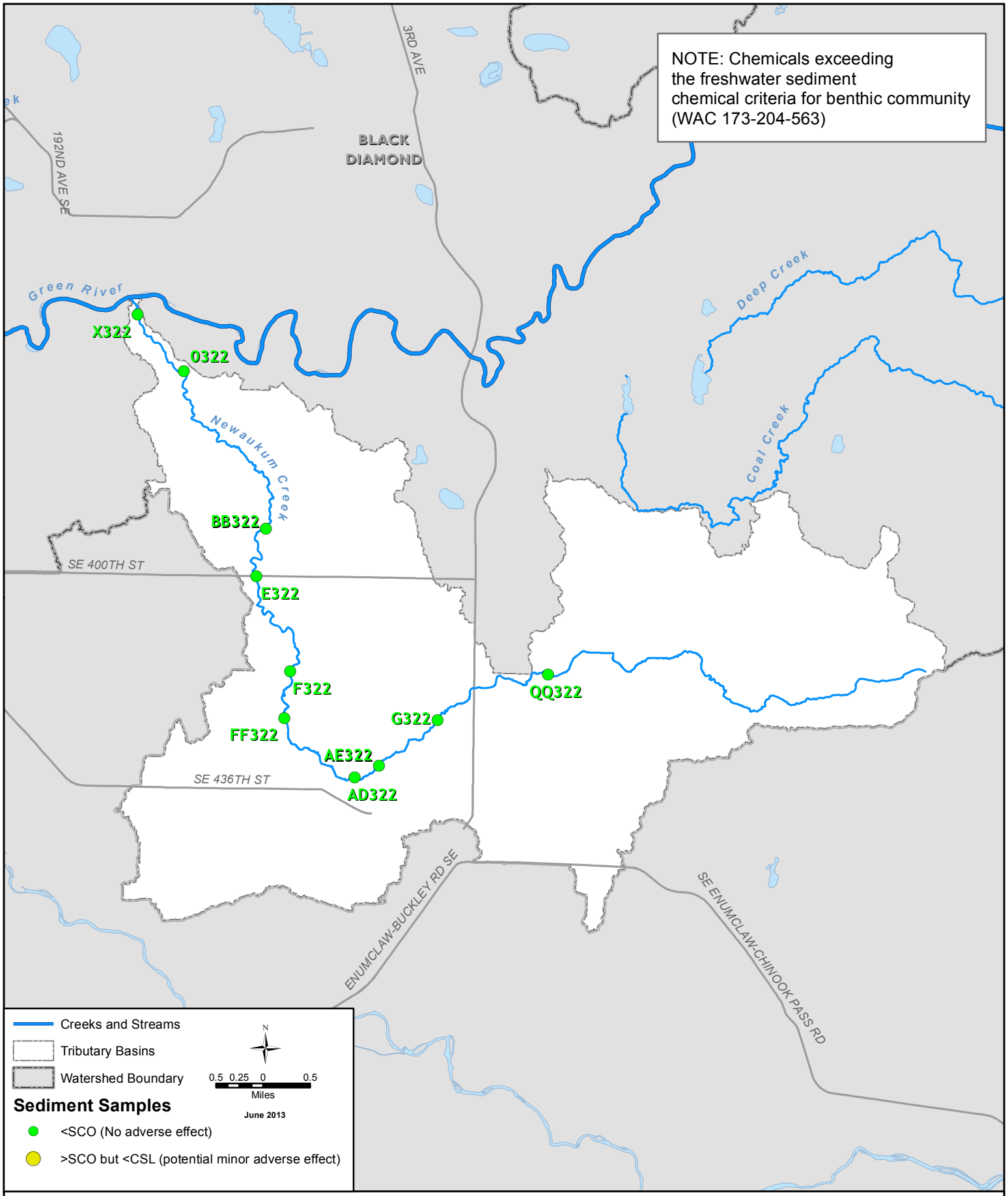
Map 5

Spatial Distribution of Dioxin Toxicity Equivalent (TEQ) Concentrations



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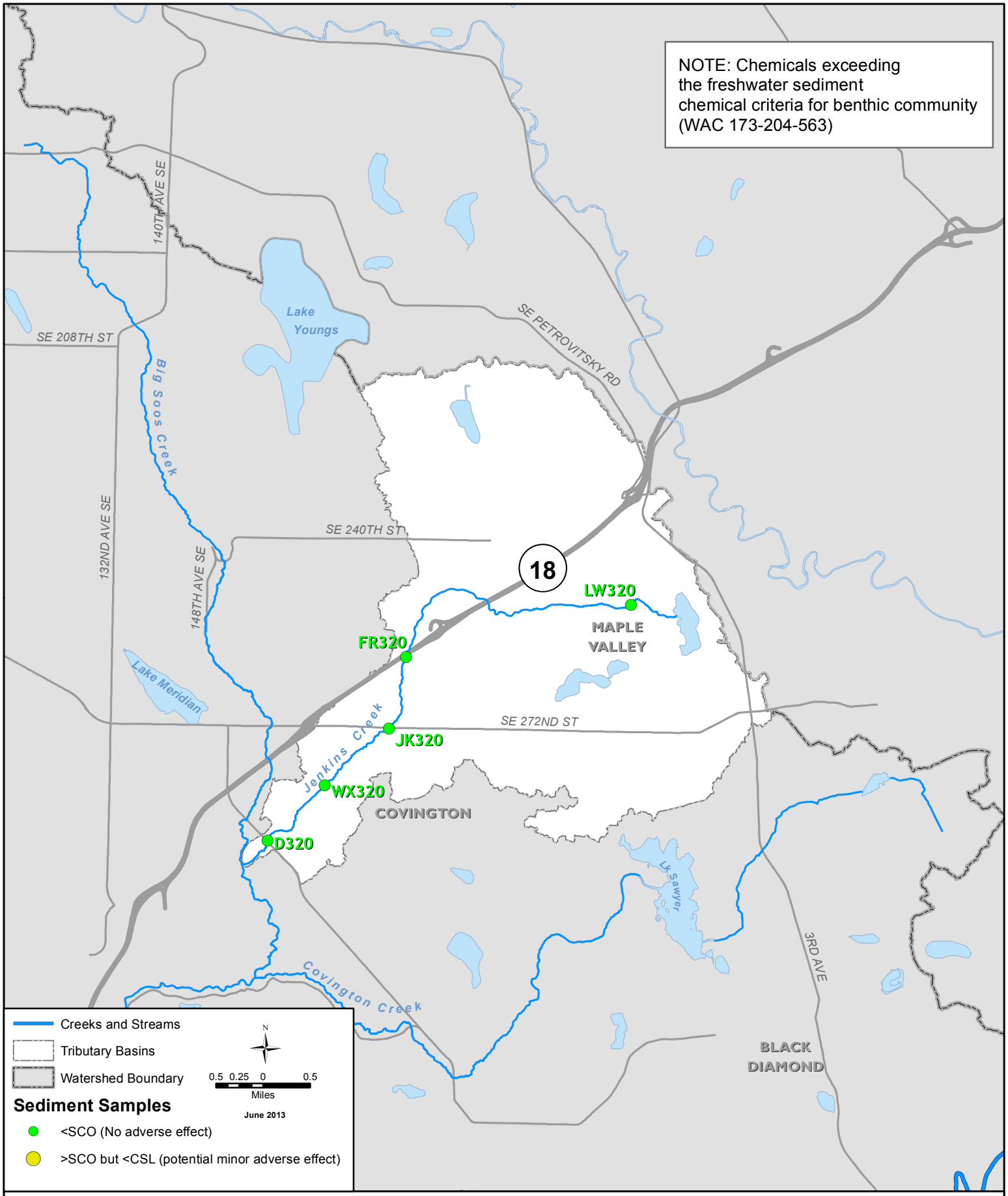
Map 6

Sediment Quality Asessment in Newaukum Creek Basin



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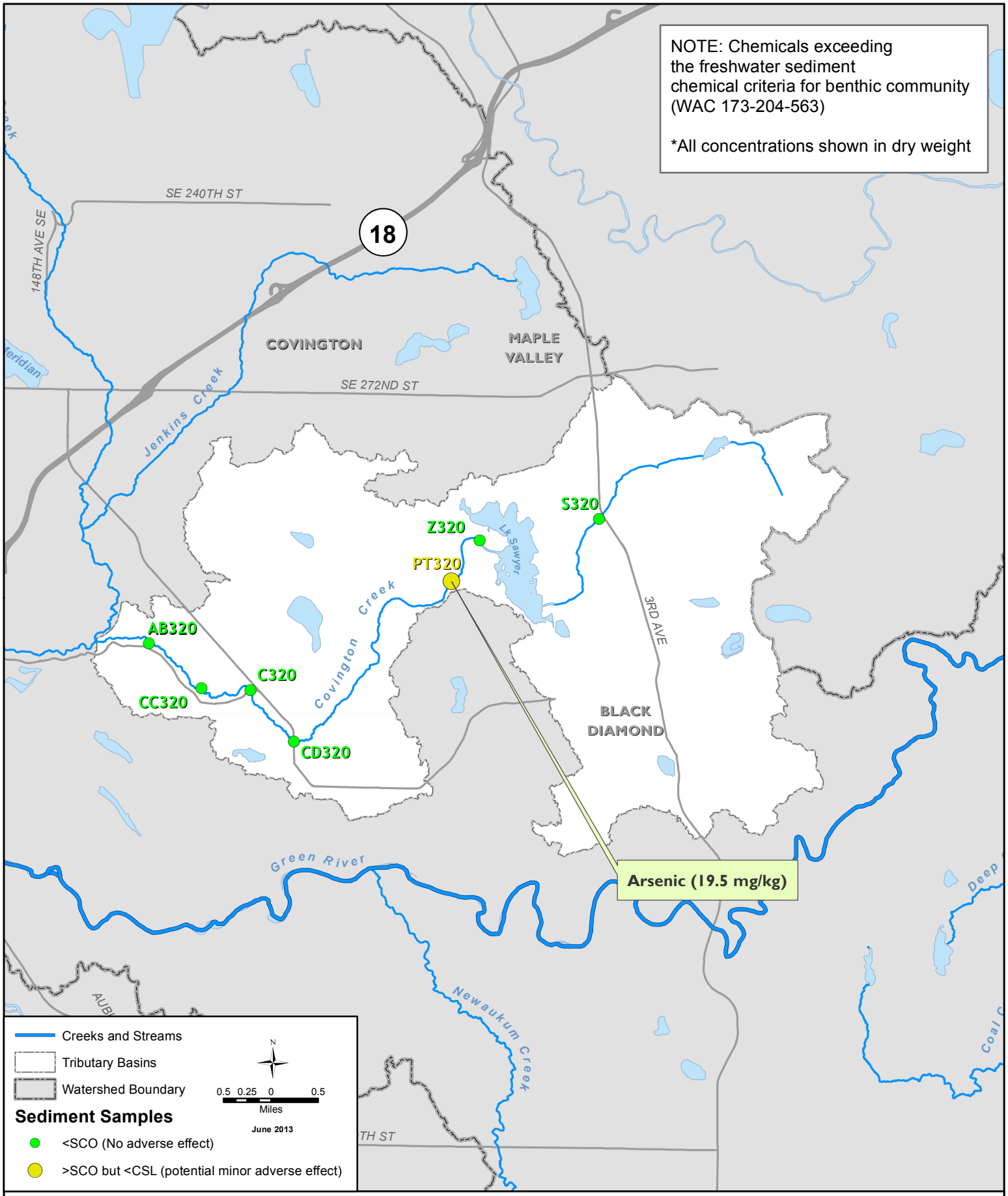
Map 7

Sediment Quality Asessment in Jenkins Basin



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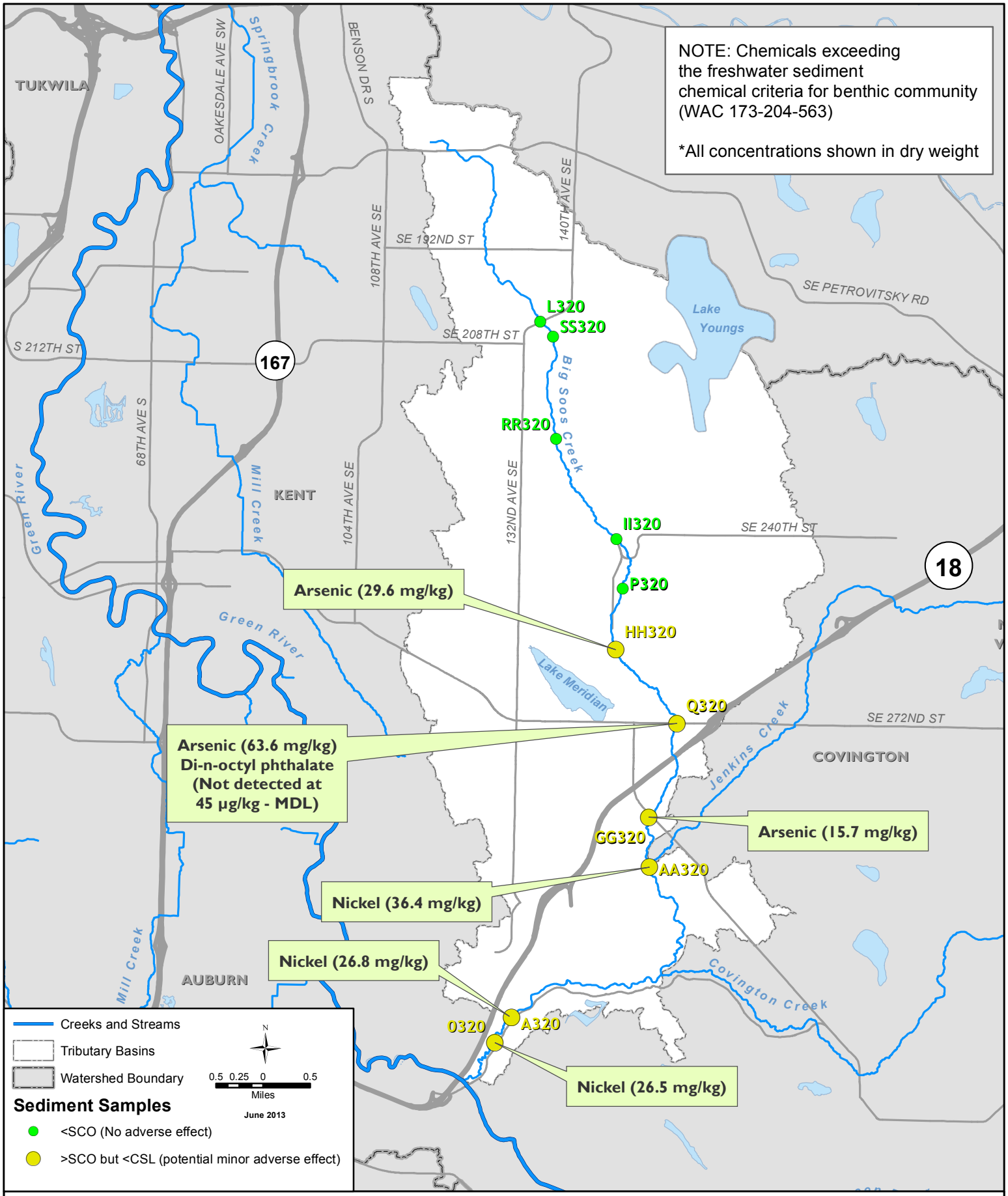
Map 8

Sediment Quality Asessment in Covington Basin



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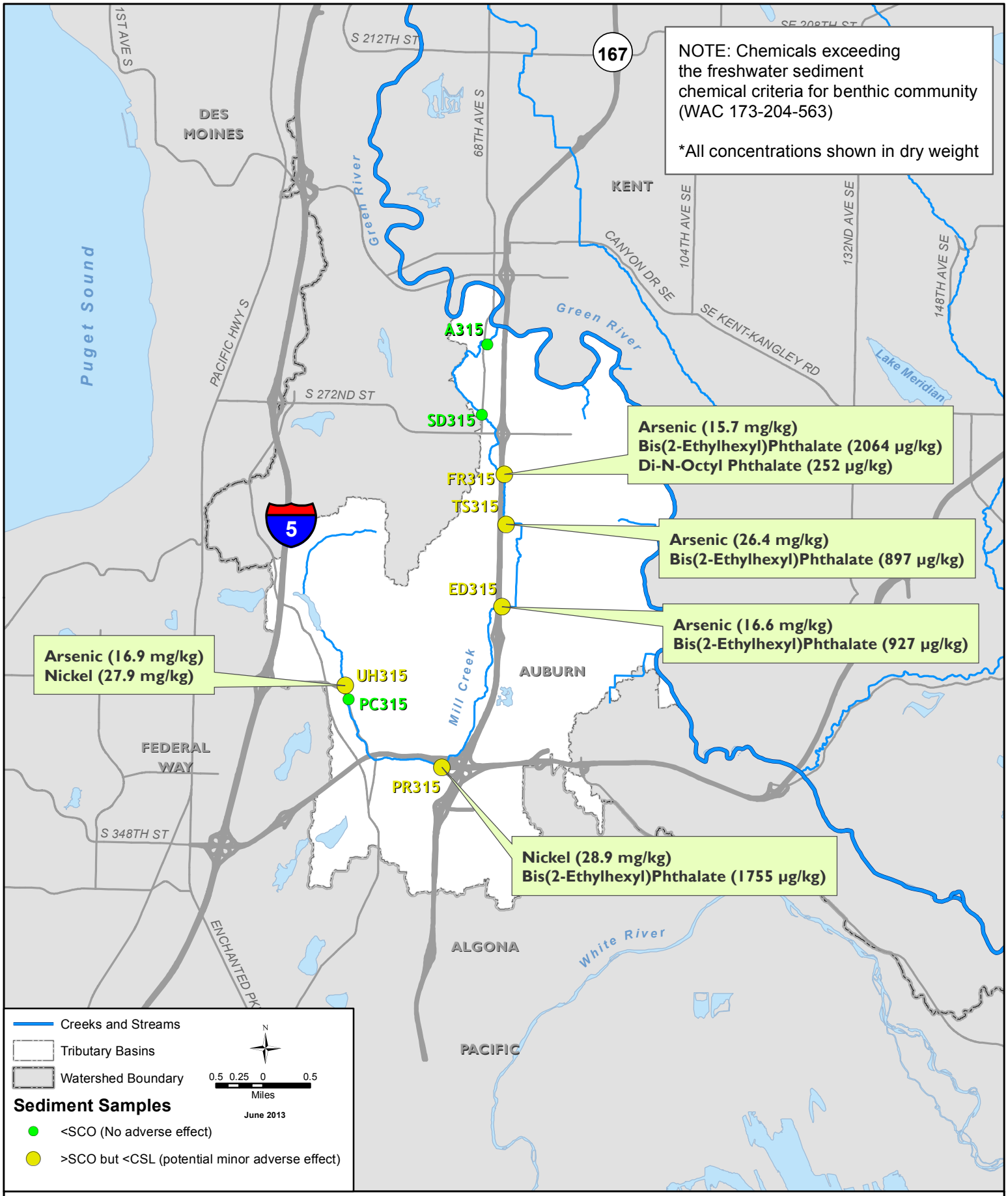
Map 9

Sediment Quality Asessment in Big Soos Basin



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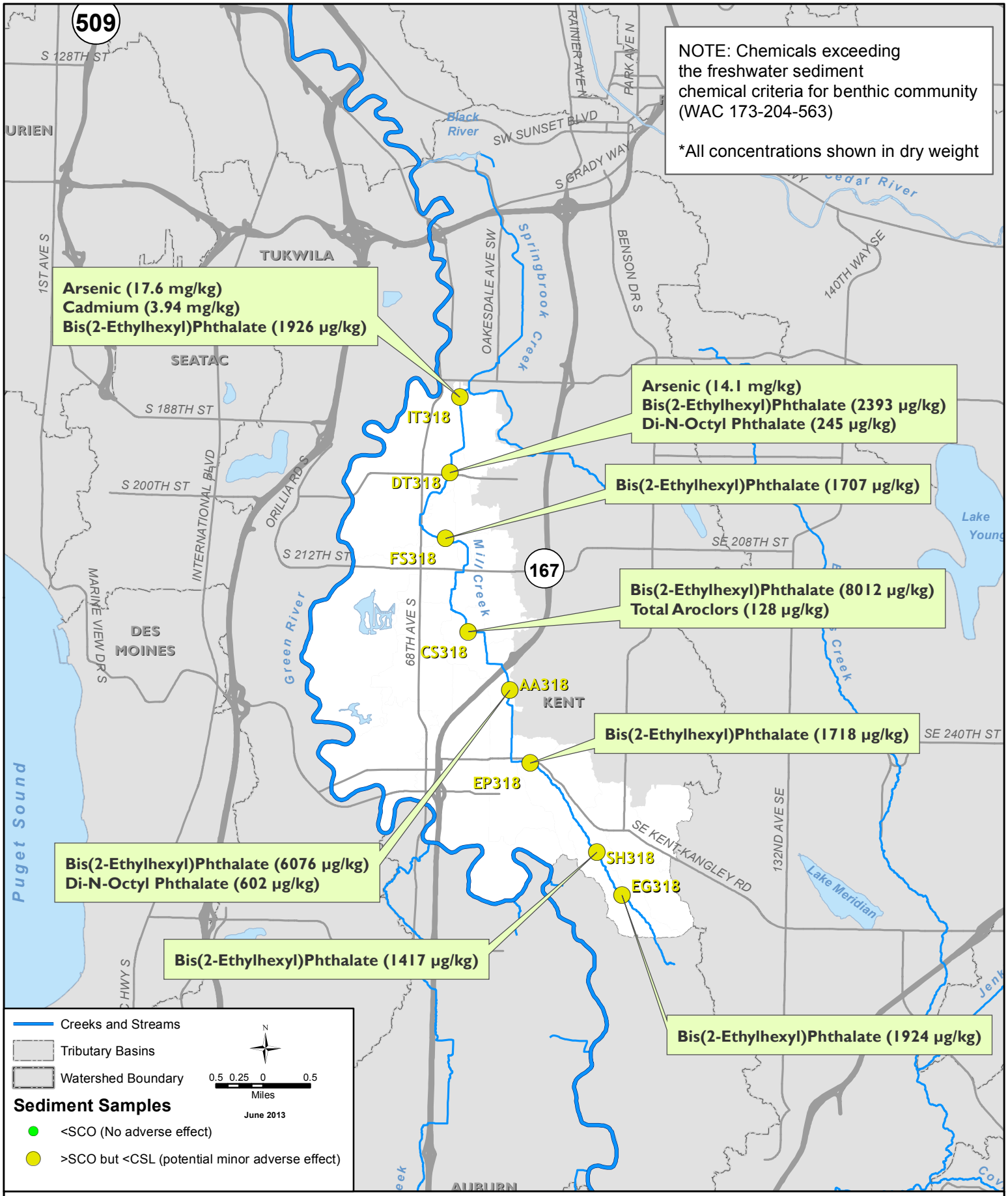
Map10

Sediment Quality Asessment in Mill Creek (Auburn) Basin



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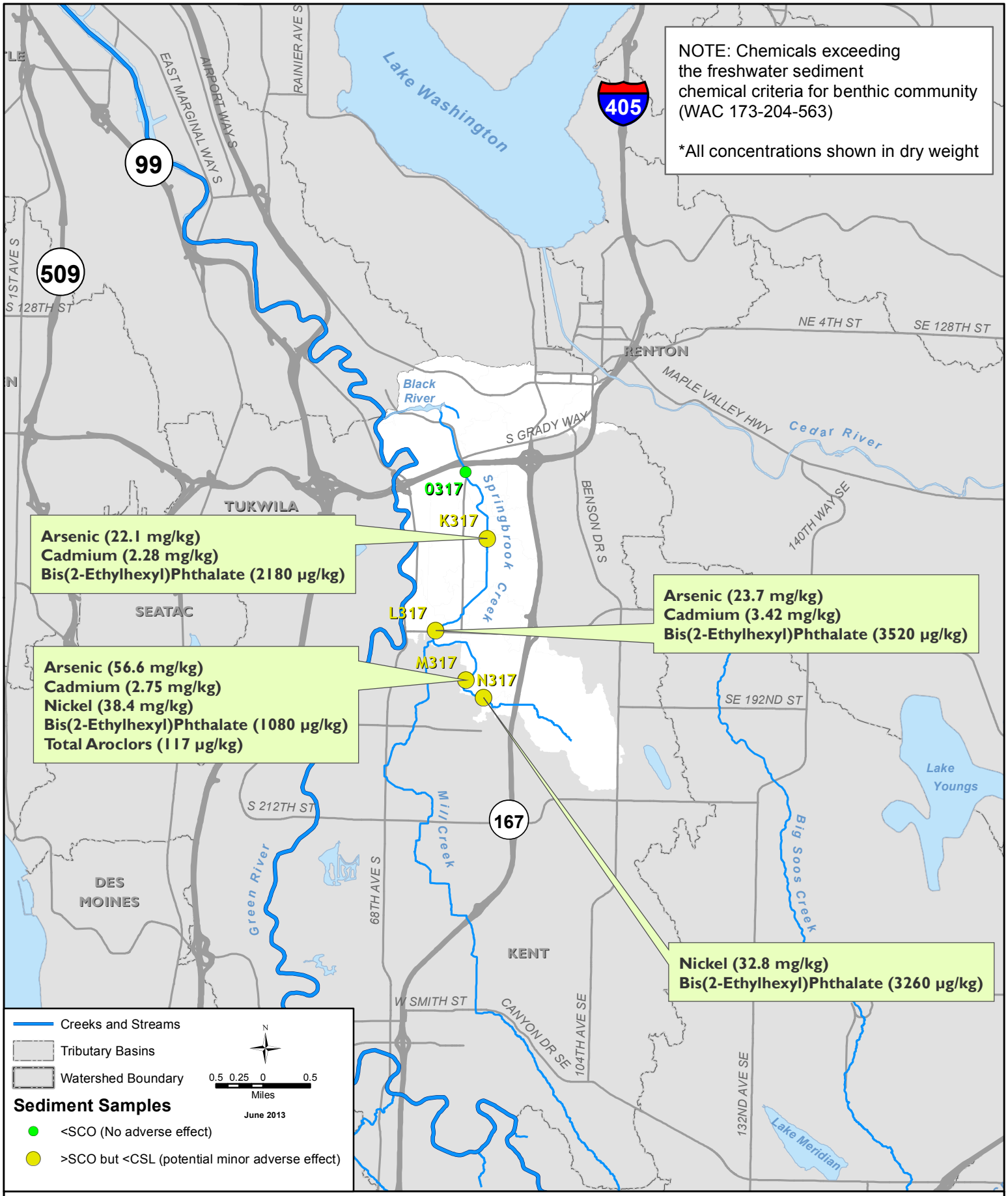
Map 11

Sediment Quality Asessment in Mill Creek (Kent) Basin



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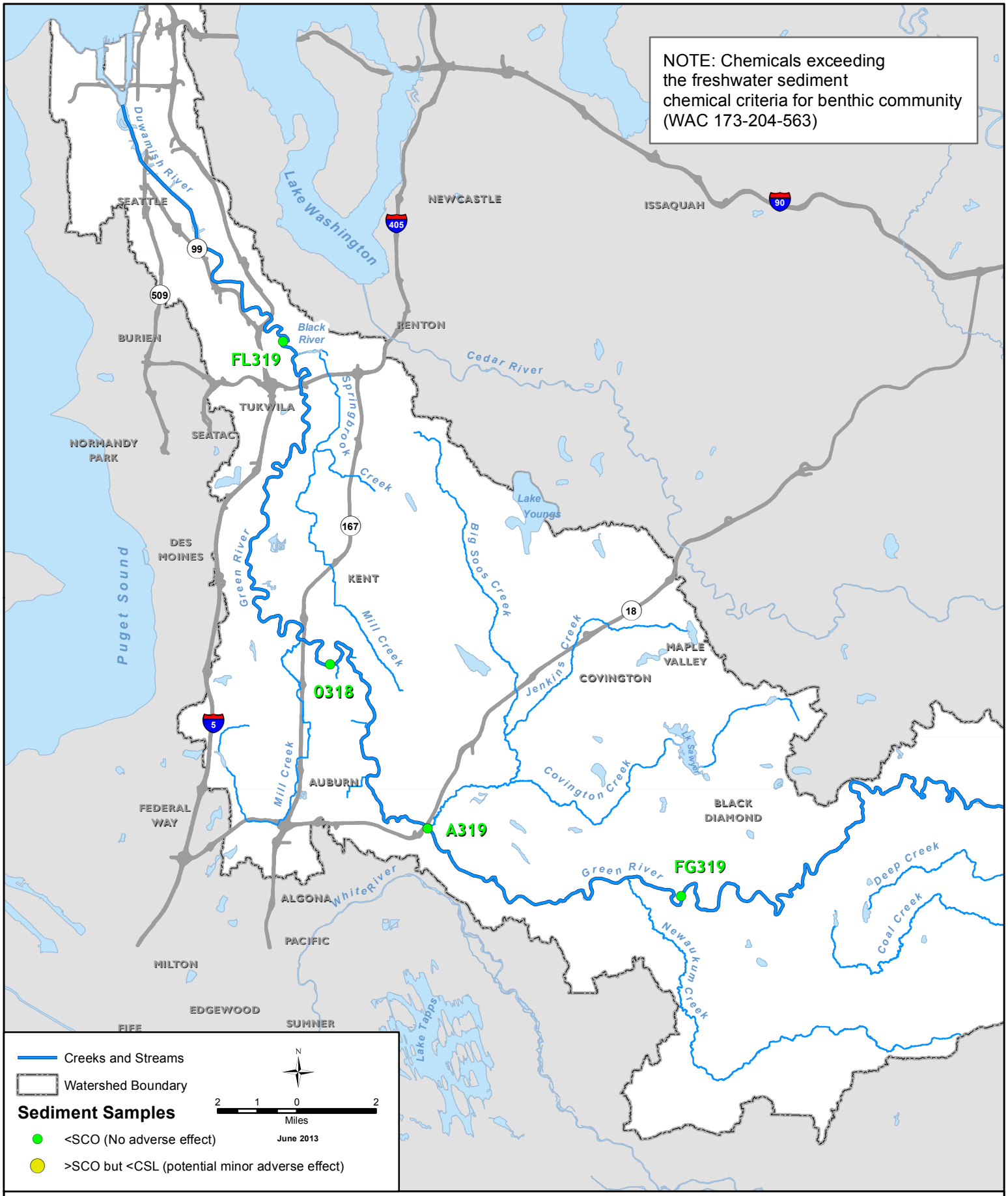
Map 12

Sediment Quality Asessment in Springbrook Creek Basin



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Map 13

Sediment Quality Asessment in Green River Basin