TETRA TECH

Memo

To: EPA Region 10 and Washington Department of Ecology

From: Tetra Tech

Date: February 17, 2015

Subject: Green/Duwamish River Watershed PLA – Existing Data and Model Evaluation (DRAFT)

1.0 INTRODUCTION

The May 2014 report, "Green/Duwamish River Watershed Pollutant Loading Assessment Technical Approach" (Technical Approach) includes a summary of existing environmental data for the Green-Duwamish watershed; and a summary of the existing computer models that have been developed to simulate water, sediment or pollutants in the watershed.

As a next step in evaluating available data, this memo summarizes further assessment of the available data to support the development of a linked watershed / receiving water / food web model. The Technical Approach proposed use of the following linked modeling tools: the LSPC[1] watershed model, the EFDC[2] receiving water model, and the Arnot and Gobas and DYMBAM[3] food-web models. Use of these models requires a variety of background data, "external forcing" data for model configuration, and supporting data for model calibration and validation. This memo addresses each of these data needs as follows:

In Section 2, the modeling domains for LSPC, EFDC, and the Food Web Model (FWM) are described.

In Section 3, pollutant data in the Green/Duwamish River watershed, the LDW, and in Elliott Bay are explored, primarily at an inventory level (i.e., counts), for suspended sediment, dioxin/furan, arsenic, metals, other SVOCs, PAHs, PCBs, pesticides, phthalates, bacteria, and conventional water quality parameters including ammonia, DO, and pH. These data are summarized across multiple media including ambient surface water, point source water, groundwater quality, ambient surface sediment, point source solids, subsurface sediment, tissue quality, and air quality.

In Sections 4 through 6, the data needs for the LSPC model, EFDC model and the FWM are outlined.

In Section 7, ongoing data collection is discussed, and Section 8 summarizes the findings of this memo.

2.0 MODELING DOMAINS

The proposed modeling system will build on the existing models only after a thorough review of the models, including modeling domain, simulated pollutants, boundary conditions, rates and constants. Summaries of the

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[1] Loading Simulation Program - C++
[2] Environmental Fluid Dynamics Code
[3] Biodynamic Model of Bioaccumulation

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existing models, based on our review of modeling reports, have been provided in the Technical Approach. Once model input files are compiled, the models will need to be reviewed to evaluate the boundary conditions, and rates and constants. The modeling domain from the existing models will be analyzed in detail to determine if any extension and refinement are needed.

2.1 EXISTING WATERSHED MODELS

Aqua Terra in conjunction with King County prepared a series of Hydrological Simulation Program-Fortran (HSPF) models for subwatersheds draining to Greater Lake Washington including Lake Union and the Duwamish/Green River (Aqua Terra and King County, 2003). The HSPF models were developed to support the Sammamish-Washington, Analysis, and Modeling Program (SWAMP), and Green River Water Quality Assessment (Green WQA) studies. The models for Black River & Springbrook Creek, Newaukum Creek, and Soos Creek drain into the Green River upstream of the LDW.

The HSPF models were constructed to examine a large number of constituents. The simulated constituents compare well with the 303(d)-listed constituents for the water column (i.e., bacteria, dissolved oxygen, pH, nutrients, and temperature), but do not include many of the 303(d)-listed constituents of concern in sediments in the LDW (i.e., polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dioxins/furans, metals, and phthalates), a significant limitation in the existing modeling for the purposes of the PLA.

Further work by King County was conducted using the System for Urban Stormwater Treatment and Analysis IntegratioN (SUSTAIN) and HSPF models, beginning in 2012 and completed in 2014 as part of a stormwater retrofit planning project for the Green River watershed. The primary focus was on flow and TSS. The domain of the watershed models appear to cover most of the subwatersheds of the Duwamish and Green rivers with exception of the LDW, and Green River upstream of Howard Hanson Dam.

2.2 WATERSHED MODEL DOMAIN

The Green/Duwamish River watershed includes four primary subwatersheds from upstream to downstream:

- Upper Green River from the Howard Hanson Dam to the headwaters, covering 220 square miles of mostly forested land;
- Middle Green River from Auburn Narrows (RM 32.0) to the Howard Hanson Dam (RM 64.5), which includes nearly 180 square miles of residential, forest, and agricultural land uses;
- Lower Green River from Tukwila (RM 11.0) to Auburn Narrows (RM 32.0), encompassing about 64 square miles of residential, industrial, and commercial land;
- Duwamish Estuary from Elliott Bay/Harbor Island to Tukwila (RM 11.0) near the confluence with the Black River, covering 32 square miles of industrial and residential areas; this subwatershed includes lateral drainage to portions of the Duwamish River downstream of the Black River as well the LDW itself.

The spatial extent of the LSPC watershed model will cover all four subwatersheds, but will focus primarily on the three subwatersheds below the Howard Hanson Dam. As discussed in the Technical Approach, the land area upstream of the dam is almost entirely forested and undeveloped, includes high elevations, and is not anticipated to be a significant source of most toxic parameters or subject to source control actions. The dam is expected to be used as a boundary condition to represent inflow into the Green River. However, the Upper Green River subwatershed will be configured in the model but disconnected from the downstream river for the calibration phase of the modeling. The purpose of configuring the Upper Green River subwatershed is for future prediction under conditions that might affect hydrology, such as climate change. In addition, two streams in the Upper Green River are listed as impaired for temperature. The Upper Green River can be reconnected to the downstream subwatersheds in the model if such prediction is needed.

The LSPC model for the Middle Green River and Lower Green River will simulate both the upland processes (e.g., build up and washoff of pollutants) and the flow and pollutant fate and transport in the river networks (using a one dimensional representation). For the subwatershed of Duwamish Estuary or LDW, LSPC will focus on the upland processes, while the flow and pollutant fate and transport in the estuary will be modeled in EFDC. A significant number of Combined Sewer Overflow (CSO) outfalls are located in this subwatershed. The combined sewer area can be represented in the LSPC model; however, LSPC is not optimized for representing CSOs. Tetra Tech anticipates that CSO data or CSO model output from the King County model will be used to represent the surface flow and loading into the LDW, while LSPC can provide subsurface flow and loads from these areas.

Items for Discussion:

- How should the CSO areas adjacent to the LDW be described/modeled within the PLA modeling framework?

2.3 EXISTING RECEIVING WATER MODELS

The Technical Approach includes a review of the existing receiving water models developed in the LDW and the Green River using EFDC and CE-QUAL-W2 frameworks. The CE-QUAL-W2 model covered the LDW and the Middle and Lower Green River (Kraft et al., 2004). The EFDC models primarily covered the LDW, portions of the Lower Green River, and Elliott Bay (AECOM, 2012; Arega and Hayter, 2004; Hayter, 2006; King County, 1999; QEA, 2008; Windward Environmental, 2010; Windward Environmental and QEA, 2008).

2.4 RECEIVING WATER MODEL DOMAIN

EFDC can be configured to simulate one dimensional, two dimensional, and three dimensional processes. EFDC could in theory be used to simulate all the rivers, ponds, lakes, and the estuary for the entire Green/Duwamish River watershed. However, the level of effort and cost to configure and calibrate EFDC models of all the rivers and lakes in the watershed would be considerably higher than those for the LSPC model. In addition, some parameters are only listed for certain water bodies (e.g.,Meridian Lake and total chlordane), and can be addressed in LSPC with a narrow spatial scope.

EFDC will be developed for the portion of the receiving waters where multi-dimensional hydrodynamics and water quality processes need to be simulated in detail and which cannot be addressed using LSPC. The EFDC model will focus on modeling the hydrodynamics and the fate and transport of pollutants in the Duwamish River and Estuary. The upstream extent is expected to cover portions of the Lower Green River similar to the King County EFDC model. The downstream spatial extent of the EFDC model is proposed to include the entire LDW, both the East and West Waterways, and a portion of Elliott Bay to account for the tidal influence. Including the East and West Waterways and Elliott Bay allows the model to simulate their impact on the LDW. However, future cleanup efforts in and around the East and West Waterways and Elliott Bay will not be evaluated in the current approach. EFDC is also able to simulate the Green River, if necessary. If more detailed data analysis reveals that the simple mechanisms in LSPC relative to EFDC cannot address the sediment-toxicant interactions in the Middle and Lower Green River, EFDC can be activated to simulate these portions.

Items for Discussion:

- Please provide input on the downgradient spatial extent of receiving water model (e.g., a location within Elliott Bay).
  Please provide input on the upgradient spatial extent of receiving water model (e.g., start of Duwamish Estuary).

2.5 EXISTING FOOD WEB MODEL

A FWM was developed in support of the Remedial Investigation to estimate PCB concentrations in tissues and sediment, with a goal of using the model to estimate risk-based threshold concentrations in sediment for the RI (Windward Environmental, 2010).

2.6 FOOD WEB MODEL DOMAIN

The FWM will use the results from EFDC to simulate the bioaccumulations of toxicants in tissues. The FWM model domain will be a sub-set of the EFDC model domain. The focus of the FWM will be in the LDW. However, it can be extended upstream if needed or simpler bio-accumulation factor approaches could be employed since LSPC does not simulate fish tissue.

Items for Discussion:

- Will the FWM focusing only on the LDW (5 mile stretch) provide enough information to understand fresh water bioaccumulation processes that are occurring upstream?

3.0 SUPPORTING DATA AND PARAMETER SELECTION

The Washington State's 2012 Water Quality Assessment and 303(d) list identifies impairments for sediment, tissue, and water for numerous pollutants in the Lower Duwamish Waterway and Green River watershed. Those pollutants, some of which are summarized by pollutant groupings (e.g. PAHs) are presented in Table 3-1.

Table 3-1. List of CWA-based impairments

Pollutants/Parameters on 303(d) List	Impaired Media
2,3,7,8-TCDD	5T
4,4'-DDD	5T
4,4'-DDE	5T
4,4'-DDT	5T
4-Methylphenol	5S
Alpha-BHC	5T
Ammonia-N	4AW
Arsenic	5ST
Bacteria	5W
Benzoic Acid	5S
Cadmium	5S
Chromium	5S
Copper	5SW
Dibenzofuran	5S
Dieldrin	5T
Dissolved Oxygen	5W
Hexachlorobenzene	5T
Lead	5S

Pollutants/Parameters on 303(d) List	Impaired Media
Mercury	5S
PAHs	5ST
PCBs	5ST
pH	5W
Phenol	5S
Phthalates	5ST
Silver	5S
Temperature	5W and 4AW
Total Chlordane	5T
Total Phosphorus	5W and 4AW
Toxaphene	5T
Zinc	5S

Key to Media:

4AW: Category 4A Water Impairments
5W: Category 5 Water Impairments
5S: Category 5 Sediment Impairments
5T: Category 5 Tissue Impairments
5ST: Category 5 Sediment Impairments and Category 5 Tissue Impairments

Tables 1-2 to 1-5 in the Technical Approach list the waterbodies on the 303(d) list, and the pollutants that exceed criteria in the water column, sediment, and tissue. Ideally, the modeling framework should simulate all these pollutants to provide a solid linkage between source and concentrations in these media. However, this represents a challenge given the number of pollutants and the complexity of linking three models to simulate the pollutants in the watershed and estuary. A significant amount of data is required to support development of these models.

In general, for model development purposes, data can be grouped to three categories: background data, external forcing data, and internal data to support calibration. For the watershed model, primary background data include elevation, slope, land use/land cover, and soils. Meteorological data comprise the majority of the forcing data for LSPC. At the watershed scale, pollutants will be represented by air deposition and assumed accumulation on the land surface. The data to support model calibration include flow and pollutant monitoring data collected in the receiving streams. Flow data are available from various USGS and King County flow gages. The pollutant loading data and the data to support water quality calibration need to be evaluated individually for specific pollutants.

For the receiving water model, the background data include primarily the bathymetry of the waterbody. Meteorology, flow, and tides are the major driving forces. Primary pollutant loading to the model will include the upstream river input (as the upstream boundary condition), CSOs, direct atmospheric deposition, and other direct discharges if applicable. River flows will be either from flow stations or directly from the watershed model. Similarly, CSO flows will be either from monitoring data or from the King County CSO model. Additional direct discharges will be incorporated as needed. Pollutant loadings to the receiving water model and the data to support the receiving water model calibration for water quality need to be evaluated individually for specific pollutants.

Additional data to support the configuration of the models include point sources, which contribute flow and pollutants. The point sources can be categorized to three primary types including industrial effluent discharges (commingled with stormwater), stormwater discharges (both treated and untreated; municipal, industrial, construction and unregulated/nonpoint), and CSOs (uncontrolled, controlled untreated, and controlled treated). Stormwater discharges will be simulated as upland processes in the proposed LSPC model. CSOs are located in the areas surrounding the LDW and will be incorporated as described previously. Industrial wastewater point sources will be included.

The watershed model serves two purposes in the PLA. The watershed model can directly address impairments in the watershed if a given pollutant is listed above the LDW. The watershed model also provides upstream flow, water temperature, suspended sediment, and pollutant inputs to the receiving water model of the LDW. Therefore, the parameters that will be modeled in the watershed model can cover both the pollutants that are listed for the LDW and the pollutants that are listed above the LDW. In addition, parameters that are listed for tissue impairments need to be addressed in the food web model. All the parameters that will be represented in the food web model will be included in the receiving water model.

To support model development, data should be available within the same time period as the model simulation. It is expected that model development will place a priority on data collected within at least the past ten years. Data collected prior to this period will also be needed, particularly for the watershed model.

In addition to the parameters in the impairment lists, other parameters that may influence these parameters can also be included. For example, phosphorus (and related causal and response parameters relative to eutrophication) could be included in the model to simulate complete eutrophication kinetics.

Based on information developed in the Technical Approach, a total of at least 50 pollutants/parameters may need to be addressed for the LDW and therefore included in the watershed and receiving water model. The data for individual parameters except the PAHs, PCBs, and phthalates were summarized for this memo; the PAHs, PCBs, and phthalates were grouped together for this data summary. Table 3-2 shows the counts for data collected in the LDW for each parameter during the recent ten years (through 2012). Table 3-3 summarizes all the data collected historically. The 50 original parameters (excluding sediment bioassay) can be categorized into twelve parameter groups as follows: bacteria, dioxin/furan, DO, metals, nutrients, other semivolatile organic compound (SVOCs), PAHs, PCBs, pesticides, pH, phthalates, and temperature.

As shown in Table 3-2 and Table 3-3, data are available with different degrees of sufficiency depending on the media. Models can be configured and calibrated for these parameters to varying degrees.

Table 3-4 lists the waterbodies that are on the 303(d) list in the watershed. Table 3-5 lists the data available for the parameters on the 303(d) list in the watershed excluding the LDW. A small number of parameters exist that do not overlap with LDW-based impairments or related causal variables such as nutrients: hexachlorobenzene, total chlordane, and toxaphene.

Items for Discussion:

- Ecology and EPA recommend focusing this effort on toxics, and not including conventional parameter impairments due to the differences in necessary modeling and management strategies. What is the TAC's recommendation?
- Which toxic parameters should be modeled in detail? Which can be represented by indicator pollutants or surrogates?

Table 3-2. Data available during the recent ten years in LDW (counts)

Parameters on 303(d)	Impaired Media	Ambient Surface Water Data	Point Source Reporting	Groundwater Quality Data	Ambient Surface Sediment	Point Source Solids	Subsurface Sediment Data	Tissue Quality Data	Air Quality Data
Ammonia-N	4AW	39	27	193	390	0	54	0	0
Temperature	5W	1,567	0	12	0	0	0	0	0
Dissolved Oxygen	5W	537	0	81	112	0	0	0	0
Bacteria	5W	428	19	6	0	0	0	0	0
pH	5W	405	150	136	1	0	0	0	0
2,3,7,8-TCDD	5T	0	0	8	633	102	120	13	26
Arsenic	5ST	21	272	1,628	1,205	1,574	388	328	72
Cadmium	5S	0	300	1,288	1,118	487	488	296	72
Chromium	5S	0	272	1,350	1,135	485	489	294	72
Copper	5S	0	296	1,207	1,216	1,539	489	294	72
Lead	5S	0	300	1,763	1,214	1,573	494	296	72
Mercury	5S	0	289	1,238	1,237	1,406	533	293	72
Silver	5S	0	271	464	1,056	494	488	293	72
Zinc	5S	0	296	1,237	1,200	1,531	488	293	72
4-Methylphenol	5S	0	166	589	1,027	1,141	405	291	0
Benzoic Acid	5S	0	149	631	1,046	1,139	404	291	0
Dibenzofuran	5S	0	240	994	1,153	1,165	373	292	0
Phenol	5S	0	167	662	1,046	1,284	409	290	0
PAHs	5ST	33	256	2,105	1,295	1,376	431	296	73
PCB	5ST	43	174	477	1,914	1,865	1,182	466	25
4,4'-DDD	5T	2	48	48	343	2	182	311	0
4,4'-DDE	5T	89	48	48	346	2	185	311	0
4,4'-DDT	5T	2	48	72	346	2	185	311	0
Alpha-BHC	5T	2	48	49	279	2	87	312	0
Dieldrin	5T	89	48	83	350	2	180	312	0
Phthalates	5ST	0	181	705	1,078	1,154	409	304	0

Note:

4AW: Category 4A Water Impairments

5W: Category 5 Water Impairments

5S: Category 5 Sediment Impairments

5T: Category 5 Tissue Impairments

5ST: Category 5 Sediment Impairments and Category 5 Tissue Impairments

Table 3-3. All historical data available in LDW (counts)

Parameters on 303(d)	Impaired Media	Ambient Surface Water Data	Point Source Reporting	Groundwater Quality Data	Ambient Surface Sediment	Point Source Solids	Subsurface Sediment Data	Tissue Quality Data	Air Quality Data
Ammonia-N	4AW	489	27	196	521	0	54	0	0
Temperature	5W	2,025	0	12	1	0	0	0	0
Dissolved Oxygen	5W	1,046	0	81	120	0	0	0	0
Bacteria	5W	603	19	6	0	0	0	0	0
pH	5W	1,057	150	223	211	0	2	0	0
2,3,7,8-TCDD	5T	0	0	8	729	102	120	17	26
Arsenic	5ST	413	272	1,630	2,998	1,590	585	464	72
Cadmium	5S	403	300	1,290	2,870	495	712	380	72
Chromium	5S	381	272	1,352	2,571	493	645	366	72
Copper	5S	392	296	1,209	3,011	1,555	713	428	72
Lead	5S	397	300	1,767	3,014	1,589	718	432	72
Mercury	5S	30	289	1,240	2,988	1,423	757	471	72
Silver	5S	404	271	466	2,679	502	712	381	72
Zinc	5S	403	296	1,239	2,947	1,547	712	377	72
4-Methylphenol	5S	94	166	589	2,463	1,150	583	407	0
Benzoic Acid	5S	94	149	631	2,299	1,148	582	407	0
Dibenzofuran	5S	94	240	994	2,649	1,174	551	409	0
Phenol	5S	94	167	662	2,619	1,292	587	408	0
PAHs	5ST	245	256	2,105	2,974	1,384	609	453	73
PCB	5ST	43	174	477	4,180	1,925	1,541	934	25
4,4'-DDD	5T	2	48	48	1,110	2	289	554	0
4,4'-DDE	5T	89	48	51	1,124	2	292	557	0
4,4'-DDT	5T	2	48	72	1,088	2	292	548	0
Alpha-BHC	5T	2	48	49	868	2	130	504	0
Dieldrin	5T	89	48	83	1,262	2	307	535	0
Phthalates	5ST	94	181	705	2,685	1,163	588	422	0

Table 3-4. Parameters on 303(d) list in the watershed (excluding the LDW)

Watershed	Water Body	Impaired Media	Parameters on 303(d)	Parameter Group
Duwamish River and Estuary	Longfellow Creek	5W	Bacteria	Bacteria
	Longfellow Creek	5W	Dissolved Oxygen	Conventional
Lower Green	Angle Lake	5W	Bacteria	Bacteria
	Black River	5W		Bacteria
	Hill (Mill) Creek	5W		Bacteria
	Mullen Slough	5W		Bacteria
	Springbrook (Mill) Creek	5W		Bacteria
	Unnamed Creek (WDF# 09.0046)	5W		Bacteria
	Black River	5W	Dissolved Oxygen	Conventional
	Hill (Mill) Creek	5W		Conventional
	Mullen Slough	5W		Conventional
	Springbrook (Mill) Creek	5W		Conventional
	Unnamed Creek (WDF# 09.0046)	5W		Conventional
	Hill (Mill) Creek	5W	Temperature	Conventional
	Mullen Slough	5W		Conventional
	Hill (Mill) Creek	5W	Copper	Metals
	Fenwick Lake	5W	Total Phosphorus	Nutrients
	Unnamed Pond	5W		Nutrients
Middle Green	Big Soos Creek	5W	Bacteria	Bacteria
	Covington Creek	5W		Bacteria
	Crisp Creek	5W		Bacteria
	Jenkins Creek	5W		Bacteria
	Little Soos Creek	5W		Bacteria
	Little Soosette Creek	5W		Bacteria
	Meridian Lake	5W		Bacteria
	Newaukum Creek	5W		Bacteria
	Soosette Creek	5W		Bacteria
	Unnamed Creek (Tributary to Newaukum Creek)	5W		Bacteria
	Wilderness Lake	5W		Bacteria
	Big Soos Creek	5W	Dissolved Oxygen	Conventional
	Covington Creek	5W		Conventional
	Little Soos Creek	5W		Conventional
	Little Soosette Creek	5W		Conventional
	Newaukum Creek	5W		Conventional
	Unnamed Creek (Tributary to Newaukum Creek)	5W		Conventional
	Big Soos Creek	5W	Temperature	Conventional
	Little Soos Creek	5W		Conventional
	Newaukum Creek	5W		Conventional
	Newaukum Creek	4AW		Conventional
	Ravensdale Creek	5W		Conventional
	Unnamed Creek (Tributary to Newaukum Creek)	5W		Conventional
	Meridian Lake	5W	Total Phosphorus	Nutrients
	Sawyer Lake	4AW		Nutrients
	Meridian Lake	5T	2,3,7,8-TCDD	Dioxin/Furan
	Sawyer Lake	5T		Dioxin/Furan
	Meridian Lake	5T	Dieldrin	Pesticides
	Meridian Lake	5T	Hexachlorobenzene	Other SVOCs
	Meridian Lake	5T	PCB	PCBs
	Sawyer Lake	5T		PCBs

Watershed	Water Body	Impaired Media	Parameters on 303(d)	Parameter Group
	Meridian Lake	5T	Total Chlordane	Pesticides
	Meridian Lake	5T	Toxaphene	Pesticides
	Newaukum Creek	5W	Copper	Metals
Upper Green	Gale Creek	5W	Temperature	Conventional
	Smay Creek	5W		Conventional
Lower, Middle, and Upper Green	Green River	5W	Bacteria	Bacteria
	Green River	5W	Dissolved Oxygen	Conventional
	Green River	5W	Temperature	Conventional
	Green River	4AW		Conventional
	Green River	4AW	Ammonia	Nutrients

Table 3-5. Data available during the recent ten years in the watershed excluding the LDW (counts)

Watershed	Impaired Media	Parameters on 303(d)	Ambient Surface Water Data	Point Source Reporting	Groundwater Quality Data	Ambient Surface Sediment	Point Source Solids	Subsurface Sediment Data	Tissue Quality Data	Air Quality Data
Duwamish River and Estuary	5W	Bacteria	603	19	6	0	0	0	0	0
	5W	Dissolved Oxygen	1,046	0	81	120	0	0	0	0
Lower Green	5W	Bacteria	534	0	0	5	0	0	0	0
	5W	Dissolved Oxygen	1,619	0	112	6	0	0	0	0
	5W	Temperature	788	0	0	1	0	0	0	0
	5W	Copper	301	0	47	56	0	0	0	32
	5W	Total Phosphorus	44	0	0	5	0	0	0	0
Middle Green	5W	Bacteria	852	2	0	0	0	0	0	0
	5W	Dissolved Oxygen	6,066	0	39	6	0	0	0	0
	5W and 4AW	Temperature	2,219	0	0	2	0	0	0	0
	5W and 4AW	Total Phosphorus	76	0	0	21	0	0	0	0
	5T	2,3,7,8-TCDD	0	0	0	3	0	0	4	0
	5T	Dieldrin	9	0	0	37	0	0	10	0
	5T	Hexachlorobenzene	1	0	0	37	0	0	29	0
	5T	PCB	28	0	0	37	0	0	30	0
	5T	Total Chlordane	0	0	0	0	0	0	0	0
	5T	Toxaphene	1	0	0	37	0	0	8	0
	5W	Copper	222	0	0	59	0	0	2	0
Upper Green	5W	Temperature	793	0	0	1	0	0	0	0
Lower, Middle, and Upper Green	5W	Bacteria	1,396	2	0	5	0	0	0	0
	5W	Dissolved Oxygen	7,712	0	151	13	0	0	0	0
	5W	Temperature	3,800	0	0	4	0	0	0	0
	4AW	Ammonia	14	0	0	26	0	0	0	0

4.0 DATA FOR LSPC CONFIGURATION AND CALIBRATION

4.1 WATERSHED MODEL CONFIGURATION AND CALIBRATION

Configuring the LSPC watershed water model requires preparation of multiple datasets to characterize the watershed. To simulate hydrology, meteorology and inflow conditions must be characterized in addition to the physical characteristics of the watershed. For the water quality component, atmospheric deposition, inflow quality, and point sources need to be characterized.

The LSPC model will be built upon King County's previous HSPF modeling of the Duwamish and Green River watershed. Model parameters will be used as appropriate as a starting point for parameterization of the LSPC model. The existing HSPF model can also be used during development as a guide to assure that watersheds and water bodies are configured correctly and have proper connectivity. Watershed delineation will be evaluated and updated if needed. Updated land cover information may be incorporated into LSPC. These efforts will ensure the consistency of the proposed LSPC and the existing HSPF while refining the delineation and introducing new data.

4.1.1 Driving Forces for Hydrology

Boundary forcing data are used to characterize processes outside of the model domain that drive the algorithms within the model. For example, lateral inflows and upstream contributions of contaminants are boundary conditions that represent independent variables when not explicitly simulated.

LSPC boundary forcing conditions for hydrology include meteorological, flow, temperature, and dissolved oxygen representation. Meteorology data will be applied across the LSPC model domain, while the other parameters will be applied at the likely upstream inflow boundary on the Green River, located just below the Howard Hanson Dam.

4.1.1.1 Meteorological Data

Meteorological data were predominantly collected from the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC) surface airways stations and can be used to support hydrodynamic and watershed modeling. Atmospheric forcing data include precipitation, air temperature, wind speed, dew point, cloud cover, evapotranspiration, and solar radiation.

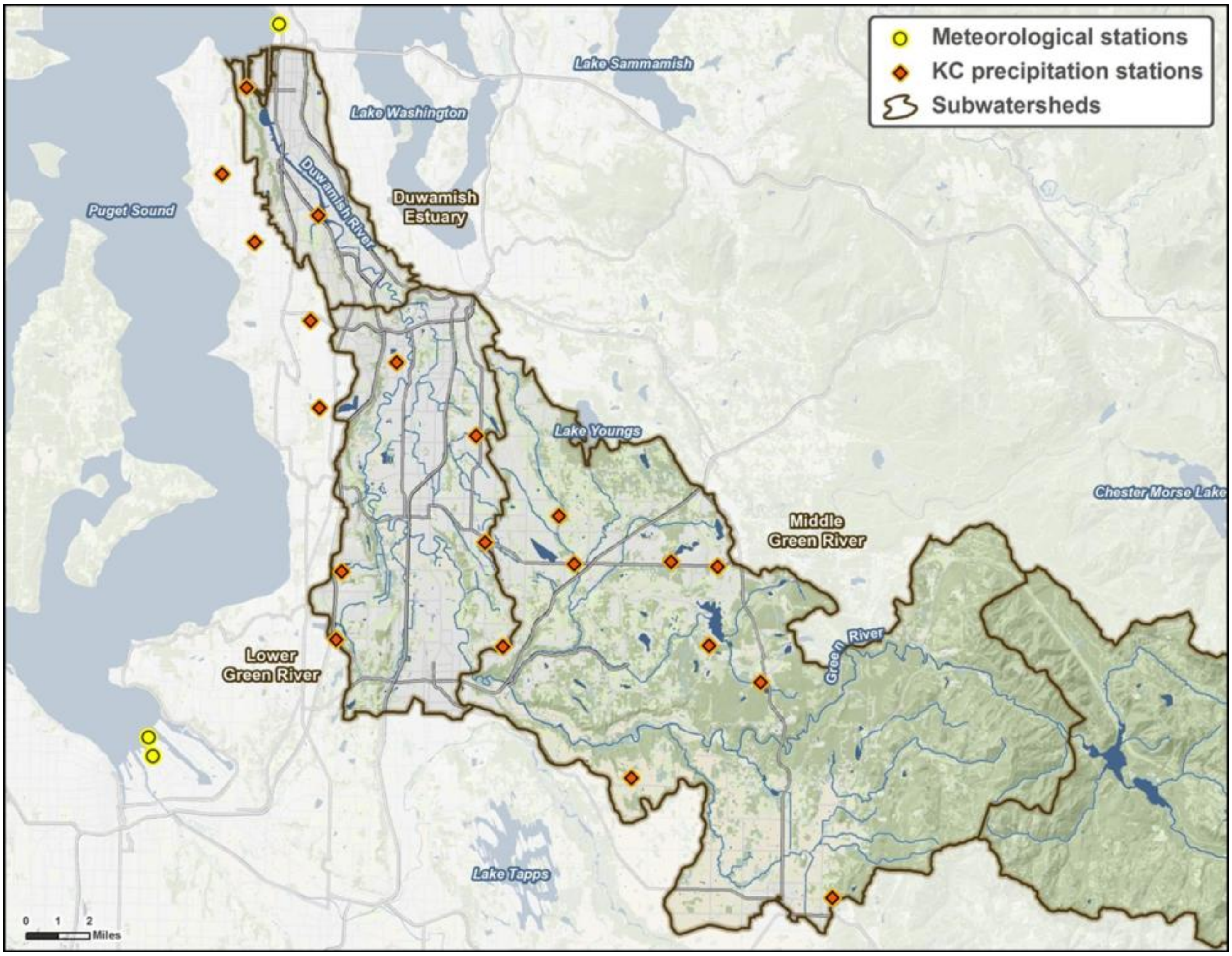

Figure 4-1. Precipitation and meteorological stations in the Green/Duwamish watershed

The figure above shows the meteorological and precipitation stations identified in the Technical Approach. The data from these stations have not yet been obtained. Additional stations were identified in the BASINS dataset for the Duwamish/Green watershed that can be used to fill spatial gaps in the meteorological data, especially in the Upper Green watershed. The BASINS data also provide additional precipitation gages throughout the watershed.

Precipitation varies considerably in the greater Seattle region, and the large watershed is subject to a spectrum of precipitation patterns. For example, annual precipitation records from 1971-2000 in the central part of the study area at Landsburg show an annual average precipitation of 56 inches, while data in the upstream portion of the watershed recorded at Cougar Mountain indicate almost double that value, at over 100 inches.

Precipitation stations shown in Figure 4-1 cover the Duwamish, and Lower Green Rivers well. Stations on the Middle and Upper Green Rivers are sparse, but additional stations have been identified in the BASINS data for the Duwamish/Green River system.

In addition to these point observations, high resolution Parameter elevation Regression on Independent Slope Model (PRISM) climate data are available to fill the gaps of weather data to support the model configurations. These data are grid-based and cover the entire modeling area. The North American Land Data Assimilation System (NLDAS) also provide grid based climate data. These point observation data and grid based data will be used together, and the spatial and temporal coverage will be sufficient to represent hydrology in the LSPC domain.

4.1.1.2 Inflow Data

The Technical Approach proposes simulating the Lower and Middle Green Rivers up to the Howard Hanson Dam. A USGS gage located just downstream of the Howard Hanson Dam provides flow data encompassing the modeling time period of 1993-2013, and will be used as a boundary condition for inflow data. The area upstream of Howard Hanson Dam drains approximately 200 square miles of mostly forested land. Dam and reservoir stage-storage-discharge data are available but have not yet been obtained.

4.1.1.3 Temperature Data

The USGS gage below Howard Hanson Dam described above does not include temperature data. Stream gages further downstream do collect water temperature data, as have discrete studies. However, water temperatures at this boundary may exhibit less variation as a result of the proximity to the large upstream reservoir. The large volume stabilizes water temperature to a greater degree than a free-flowing river. In addition, the lower water column of Howard Hanson Reservoir is discharged through two Tainter Gates, which control the reservoir and release colder flows.

More stable temperature representation can be achieved by averaging either water (or air) temperatures over a period to obtain a moving average. A seven-day average can be used for these purposes. Alternatively, if the Upper Green River is directly simulated (but detached from the Middle Green River), the simulated temperature time series can be associated with the dam boundary flows.

4.1.1.4 Dissolved Oxygen Data

Observed dissolved oxygen data are not available at the USGS gage below Howard Hanson Dam. Although observations exist further downstream on the Green River, these might not accurately represent oxygen levels discharged from the reservoir. Oxygen concentrations in the dam outflow will be assigned based on a saturation percentile, which is highly dependent on temperature. This emphasizes a need for accurate temperature representation from Howard Hanson Dam, though much of the influence should attenuate prior to reaching the Lower Duwamish Waterway.

4.1.2 Supporting Data for Calibration of Hydrology

Flow data will also be used in the calibration effort to assess the accuracy of model results. Flow data will be compared against modeled flow to quantitatively evaluate the model performance. The USGS and King County maintain numerous stations in the Green/Duwamish system; USGS data are available at a daily interval, while King County data are available at 15-minute intervals. Figure 4-2 shows the spatial distribution of flow monitoring stations. About half of these provide data throughout a proposed modeling period of approximately 1995-2015. Notably, there is sparse data above the Howard Hanson dam in the Upper Green River subwatershed. Hydrology calibration in this largely forested area will be coarse relative to subwatersheds downstream where better flow coverage exists. The flow data should be sufficient for watershed modeling purposes and to achieve an appropriate representation of system hydrology.

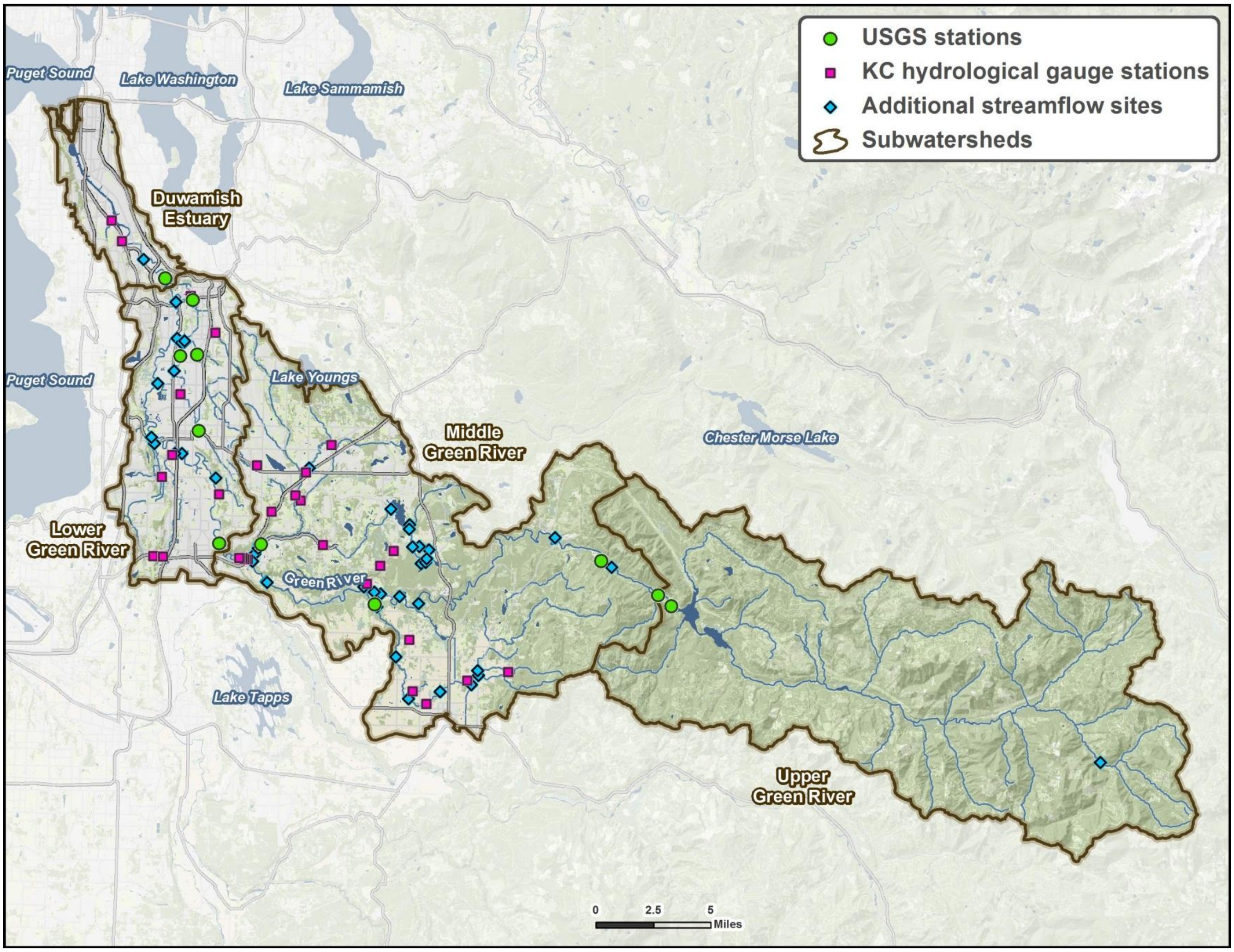

Figure 4-2. USGS and King County hydrology calibration stations in the study area

4.1.3 External Sources and Pathways of Pollutants

4.1.3.1 Atmospheric Deposition

Atmospheric deposition of PAHs, dioxins/furans, PCBs and arsenic are important sources of pollutants that may be considered a boundary condition, as these are external inputs to the watershed and receiving water models. Atmospheric deposition is also important for nutrients. Both wet and dry deposition of these contaminants occur in the watershed, and are spatially and temporally dependent. For example, arsenic deposition occurred near smelter locations prior to their closure. PCBs will have higher concentrations in air in close proximity to PCB sources, such as a building with high PCB concentrations in caulking or paint. PAHs and dioxin/furans are expected to have higher air concentrations in close proximity to transportation centers.

King County conducted a year-long bulk atmospheric deposition study in the LDW, Lower Green and Middle Green River portions of the Duwamish/Green River watershed to assess impacts of select metals, mercury, PAHs, PCB congeners, seven polychlorinated dibenzo-dioxins (PCDDs), and ten polychlorinated dibenzo-furans (PCDFs) (King County, 2013b). The study found that spatial variation in deposition rates exists, and is correlated with urban areas.

Other studies, including one of atmospheric deposition of air toxics to Puget Sound by Ecology (Brandenberger et al., 2010), provide additional information regarding deposition of contaminants. Table 4-1 below summarizes the available depositional data across these studies.

Table 4-1. Summary of air quality data (2001-2012)

Parameter Group	Number of Stations	Percent of Stations	Number of Sampling Events	Percent of Sampling Events
Arsenic	5	23%	104	4%
Conventional (relative to convential water quality parameters)	15	68%	2,571	96%
Dioxin/Furan	5	23%	43	2%
Metals	5	23%	104	4%
PAHs	5	23%	106	4%
PCBs	5	23%	42	2%
VOCs	1	5%	1	0%

Note: Shading represents pollutants that are primary human health risk drivers.

Atmospheric deposition data summarized above are available in the form of unit area loading rates, which are suitable for LSPC modeling. Parameter-specific statistics such as median, minimum and maximum rates are available, which should be sufficient for use. Raw data have not been reviewed at this stage, but can be investigated in more detail during development of the watershed model.

Items for Discussion:

- Discuss how best to represent the spatial variation in air deposition in the PLA modeling approach.

4.1.3.2 Upstream Pollutant Loadings

As discussed above with respect to hydrology, the gage below the Howard Hanson Dam is expected to serve as a boundary forcing condition to the watershed model, and provide flow and pollutants to the upstream component of the model. These forcing data will be applied to the upstream end of the Middle Green River segment and will allow for simulating attenuation down to the LDW. No water quality data or information regarding pollutants are available at the USGS gage below Howard Hanson Dam. Composition of the area draining to the reservoir does not include known sources of pollutants of concern, however new data does show that pollutants are present. The only impairments above the reservoir are for temperature (Gale Creek and Smay Creek, as shown in Table 3-4).

A sparse water quality dataset exists upstream of the Howard Hanson Dam in the Upper Green River watershed. A few ammonia, nitrate/nitrite, and orthophosphorus samples do exist, but will likely not be sufficient to fully characterize the conditions at the Howard Hanson Dam. No surface water sediment data exist upstream of the dam. These data will be reviewed in the context of regional reference watersheds when assigning boundary conditions at this location. Atmospheric deposition data will be evaluated for other pollutants with the assumption that atmospheric deposition is the only pollutant source above the Howard Hanson Dam.

4.1.3.3 Permitted Facilities

The majority of NPDES permits in the study area are general permits for stormwater (municipal, industrial and construction) and specific industrial processes (such as Sand & Gravel and Boatyards), which are proposed to be incorporated as upland processes in the LSPC watershed model. There are five individual permits in the Lower Duwamish and Lower Green watersheds. The initial data inventory conducted for the Technical Approach suggested that DMR data are limited. When available, flow and pollutant concentrations obtained from DMRs and other applicable studies would be used to improve model calibration. When DMR data does not contain the parameters to be modeled, assumptions can be made based on similar monitoring efforts. For example, there is an extensive set of storm drain solids data in the LDW that has been collected by the City of Seattle. Additional stormwater system data has been collected by Ecology and will be collected in the next 2 years under the Industrial General Stormwater Permit. If necessary, additional data may need to be collected.

4.1.4 Supporting Data for Calibration of Water Quality

Ambient water quality data will be used to calibrate and validate the watershed model for a range of pollutants. Numerous water quality stations exist in the study area that collect in-stream data on the parameters of concern. The majority of these stations are located in the Lower Green River and Lower Duwamish (which is represented in the EFDC domain - see Section 5) segments of the system. Data are also available in the Middle and Upper Green River watersheds, but the density of stations decreases sharply along the Middle Green River. Ambient water quality data availability in the Lower, Middle and Upper Green Rivers are discussed here, while data in the LDW will be discussed in the EFDC section below. Table 4-2 lists a summary of the data inventory for Green River watershed stations only.

Ambient water quality data for alkylated PAHs is not available, although some non-alkylated PAH data exist in the Lower and Middle Green segments (eight stations). Arsenic data are available at 21 stations in the Middle and Upper Green River watersheds and should be sufficient for calibration purposes. A wealth of bacteria data (67 stations) are available in the Lower, Middle and Upper Green River watersheds. Conventional parameters are also widely available in the three upper watersheds (112 stations). There are no ambient data for dioxin/furans or organometals for use in calibration (with the exception of any sampled in the ongoing data collection discussed later in this memo), but surface sediment samples are available. The surface samples could provide potency factors for pollutants where there are data. Metals data (23 stations) are common. SVOCs (4 stations) are represented by a few data points. The detailed calibration data inventory for LSPC (and EFDC) is listed in Tables A-1 through A-31 in Appendix A by pollutant group. The data presented in Table 4-2 will largely be used for LSPC calibration to ensure that accurate pollutant loads are passed to the EFDC modeling domain in the LDW, but also as boundary forcing and calibration information for the EFDC model. A number of ongoing studies by USGS, Ecology, and King County will provide important calibration data, particularly for some of the parameters with fewer data points (e.g., TSS, dioxin/furans, PAHs, PCBs). Brief summaries of these efforts are provided later in this document.

Table 4-2. Summary of data inventory in the Green River Watershed (excludes LDW)

Recent Green River ambient data for use in LSPC calibration		Stations	Samples	Begin Date	End Date
TSS	TSS	7	124	2001	2012
Dioxin/Furan	2,3,7,8-TCDD	-	-	-	-
Arsenic	Arsenic	16	224	2001	2012
Metals	Cadmium	10	102	1995	2007

Recent Green River ambient data for use in LSPC calibration		Stations	Samples	Begin Date	End Date
	Chromium	10	102	1995	2007
	Copper	11	523	1995	2009
	Lead	9	97	2002	2007
	Mercury	10	102	2002	2007
	Silver	9	97	2002	2007
	Zinc	12	313	1995	2007
SVOCs	4-Methylphenol	-	-	-	-
	Benzoic Acid	-	-	-	-
	Dibenzofuran	-	-	-	-
	Phenol	-	-	-	-
PAHs	PAHs	7	65	2007	2012
PCBs	PCBs	6	54	2005	2012
Pesticides	4,4'-DDD	-	-	-	-
	4,4'-DDE	-	-	-	-
	4,4'-DDT	-	-	-	-
	alpha-BHC	-	-	-	-
	Dieldrin	1	4	1996	2007
Phthalates	Phthalates	-	-	-	-
Bacteria	Bacteria	41	860	1999	2011
Conventional	Ammonia-N	2	14	2000	2008
	Nitrate/nitrite	45	1060	1995	2011
	Orthophosphate	45	890	1995	2011
	Organic Phosphorus	2	43	1995	2007
	Organic Carbon	41	430	2004	2012
	Dissolved Oxygen	46	5724	1995	2012
	pH	46	5870	1995	2012

In addition to the existing HSPF models and the data to support the calibration, results from other studies conducted in the watershed will also be used to support the calibration. The water quality statistical and pollutant loadings analysis conducted by King County provides significant amount of information for pollutant loadings from various land surfaces (Herrera Environmental Consultants, 2007). In addition, the *Assessment of Selected Toxic Chemicals in the Puget Sound Basin: 2007—2011 (*Ecology and King County, 2011) provides information about toxic chemical pollution in the Puget Sound region data about sources, loading, pathways, and hazards. This information will be used to support the calibration of build-up and wash-off coefficients.

5.0 DATA FOR EFDC CONFIGURATION AND CALIBRATION

Configuring the EFDC receiving water model requires preparation of multiple types of boundary conditions to represent the external forces of the study area. The boundary conditions include surface boundary conditions, open boundary conditions, and flow boundary conditions for hydrodynamics. Concentrations of the modeled parameters at the open boundary locations and loadings of the modeled parameters associated with all types of flow are needed for the contaminant/water quality model configurations. Water column and sediment data inside the modeling domain will be used to support model calibration.

As mentioned in Section 2, EFDC models have been developed covering the extent from the Lower Green River to the Elliott Bay with different model spatial resolutions and simulation periods. The proposed EFDC model will be developed maximally using the grid, boundary conditions, and rates and constants from these existing models. The new modeling domain will be extended further into Elliott Bay. New model grids will be attached to existing grids, and grid size will be revisited. The boundary conditions from the existing EFDC models need to be reviewed and compared against data to guide the development of boundary conditions for the new EFDC model. Rates and constants from the existing EFDC models will be used to assign initial estimates in the new EFDC model.

Two types of point sources are in the watershed including CSOs, and stormwater runoff (excluding the King County South outfall in Ellott Bay). Most of the point sources are stormwater outfalls and they will be modeled in LSPC. WWTP effluent will be directly represented in EFDC using DMR data depending on how far the model extends into the bay. For CSOs, a combination of LSPC model results, data, and previous CSO model results will be used to represent them in EFDC.

5.1 HYDRODYNAMIC MODEL CONFIGURATION AND CALIBRATION

5.1.1 Boundary Conditions for Hydrodynamics

5.1.1.1 Surface Boundary Conditions: Meteorological Data

The EFDC model requires data at an hourly or shorter time step to drive the hydrodynamic and water temperature simulation, mainly to capture the temperature variation under the impacts of solar radiation and air temperature. Forcing data include air pressure, air temperature, dew point temperature or relative humidity, precipitation, evaporation, solar radiation, cloud cover, and wind speed/wind direction. Evaporation can be calculated internally in EFDC and solar radiation can be estimated with clear sky solar radiation using location and the time. The EFDC modeling domain is not a large area where air pressure would change significantly, so air pressure can be assumed to be uniform throughout the modeling domain. Data for air temperature, dew point temperature or relative humidity, precipitation, cloud cover, and wind speed/direction must be provided from an external source. The meteorological data collected at Seattle-Tacoma International Airport (SEATAC) are proposed to be used to support the hydrodynamic and water quality modeling. The SEATAC data were used for the King County's CE-QUAL-W2 model that covers the Green River. In addition, NOAA tide station 9447130 at Seattle, WA is close to the mouth of Duwamish Estuary. Data of wind, air temperature, and barometric pressure are all available from 1991 to 2014. These data and the data from SEATAC will be combined together to derive the surface boundary conditions for the EFDC model.

5.1.1.2 Open Boundary Conditions: Tide

The domain of the EFDC model needs to extend into the Elliott Bay to set the open boundary far away from the study area. Open boundary data for hydrodynamics simulation including tide, salinity, and water temperature.

EFDC models have been developed by King County (1999), Arega and Hayter (2004), and AECOM (2012), and the open boundaries of these models were extended to Elliott Bay. Figure 5-1 shows the tide and marine sampling sites in and out of the Duwamish Estuary. No tide station is located right at the open boundary locations of the previous EFDC models. Tide data are available at NOAA tide station 9447130 located at the Port of Seattle. Both hourly and 6-minute water level data are available up to 2014. The open boundary conditions from the previously developed models will be compared to the tide data to determine the best data to use.

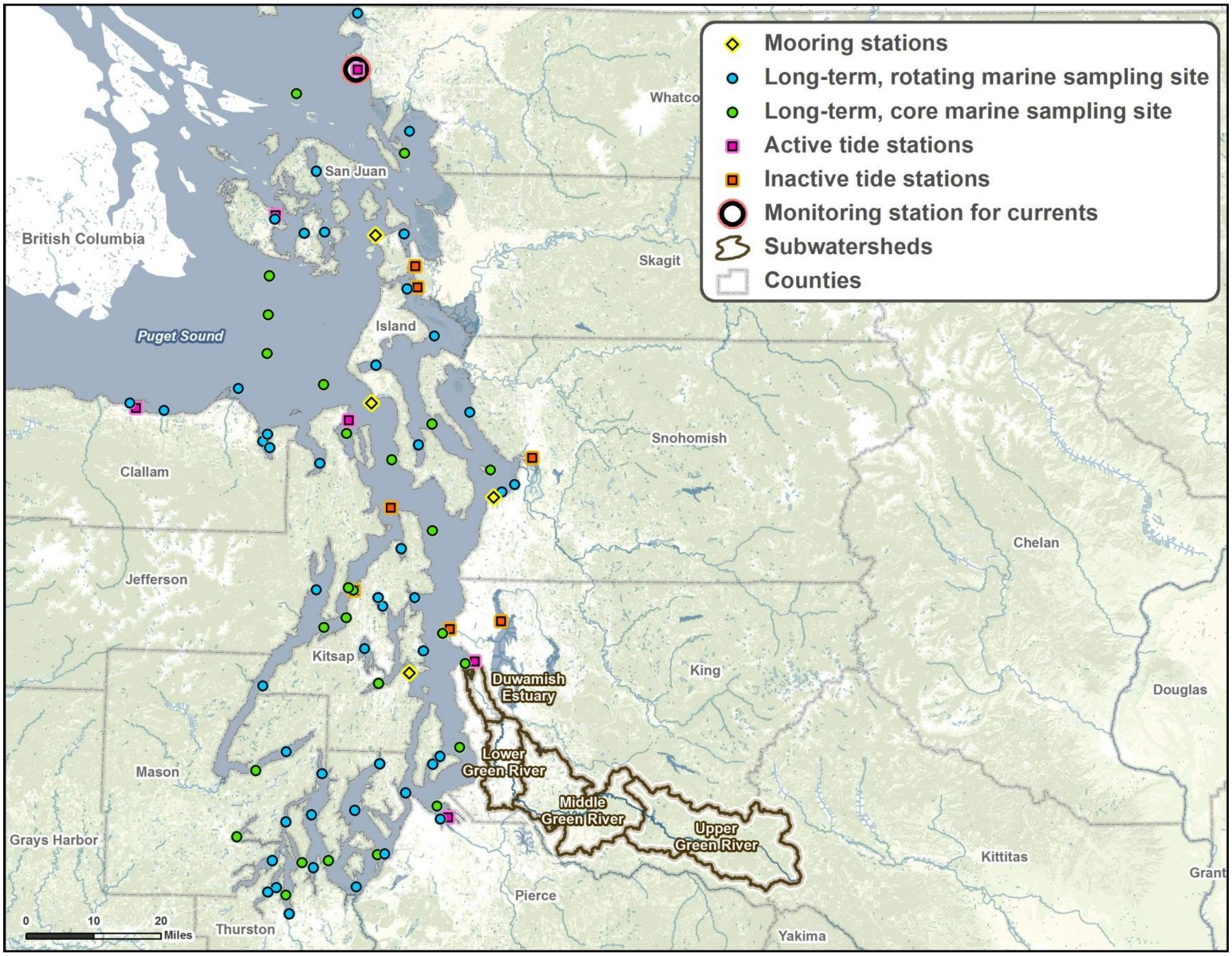

Figure 5-1. Tide and marine sampling stations

5.1.1.3 Upstream Boundary Conditions: Flow

Water enters the LDW from various sources. Green River is the major source of water to the LDW. Black River flows into the Lower Green River right above the LDW. In addition to the Green River and Black River, CSOs and other runoff from the drainage areas surrounding the LDW enter the estuary. Flow stations and data were evaluated. Figure 5-2 presents the locations of the USGS stations and King County gauge stations. The USGS station 12113350 is on the Green River at Tukwila, WA, which is close to the proposed upstream boundary location of the EFDC model. However, only gage height data are available from 1988 to 2014. Discharge data were only available from 1960 to 1984. The USGS station 12113344 is on the Green River at 200th Street at Kent, WA. The discharge data at this station are available from the end of 2011 to 2014. The USGS station 12113385 is on the Black River below Pump Station near Renton, WA. However, the discharge data span only 1995 to 1997.

Therefore, calibrated LSPC model results may provide the best alternative for the flows from Green River and Black River into the LDW.

It should be noted that the EFDC model could be extended to cover both the Middle Green River and Lower Green River. Under such circumstances, the upstream boundary location would be extended accordingly.

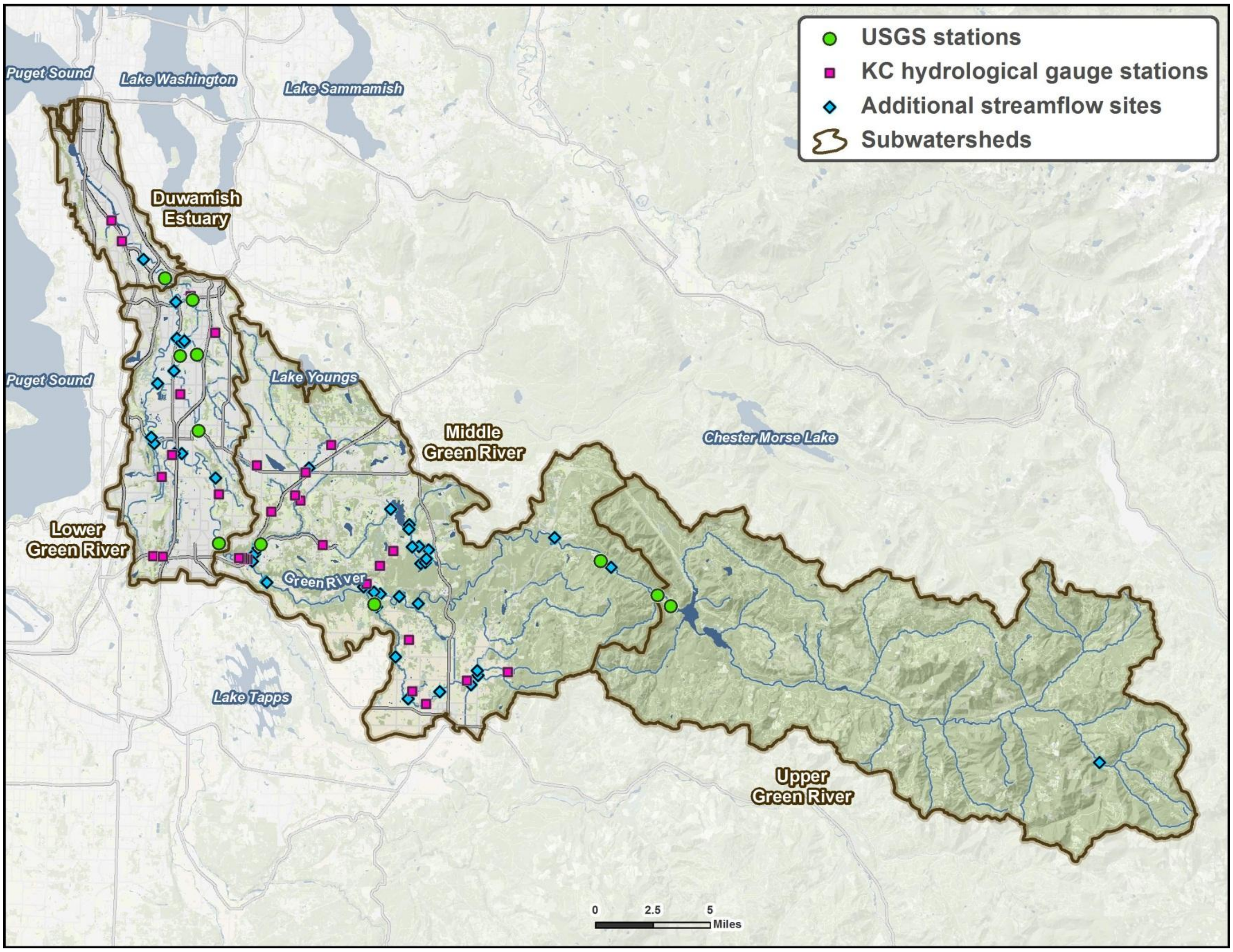

Figure 5-2. Gauges in the Green/Duwamish watershed

In addition to the flows from the main Green River and the tributary Black River, CSOs, direct surface runoff, and groundwater contributions to the LDW need to be considered. The LSPC model will be configured to simulate the total surface runoff from the areas around the LDW. However, the LSPC model is not a CSO model and it cannot predict the CSO flow. King County has developed a CSO model and it is expected that the results from this model and observed CSO data will be used to represent the CSO flows entering the LDW. If the CSO model does not cover the entire modeling period of the LSPC model, an alternative approach will be developed to estimate the CSO (e.g., regression analysis of the CSO model results and the surface runoff from these areas represented by LSPC). The LSPC model can also provide flows not included in the CSO model/data such as subsurface inputs. Finally, direct precipitation to the LDW will be incorporated.

Boundary conditions in previously developed EFDC and CE-QUAL-W2 will be reviewed as well. Depending on the time periods of the previous models and the approaches of how these boundary conditions were prepared, these boundary conditions may be used, partially used, or not used.

5.1.1.4 Upstream and Open Boundary Conditions: Salinity and Water Temperature

In addition to influences of meteorological conditions, tide, and flows, salinity and water temperature are also important factors affecting hydrodynamics. Salinity and water temperature change the density of water and may potentially cause stratifications, thus impacting vertical mixing in the water column.

Salinity data are needed at the open boundary locations. Offshore conductivity, temperature, and depth (CTD) sensor monitoring data from the King County's Puget Sound Marine Monitoring Program can be used to derive the salinity at the open boundary locations. Figure 5-3 shows the locations of the CTD monitoring sites. Salinity data at the CTD sites are available from 1998 to 2014. In addition, existing EFDC models will be reviewed and can inform salinity settings. For all other flow boundary conditions, salinity will be set to zero.

Water temperature data are also needed for the open boundary locations. Similar to the salinity, temperature data at the CTD sites can be used, and water temperatures used at the open boundary locations in previous EFDC models will be reviewed. LSPC output will provide the water temperature associated with inflow boundary conditions.

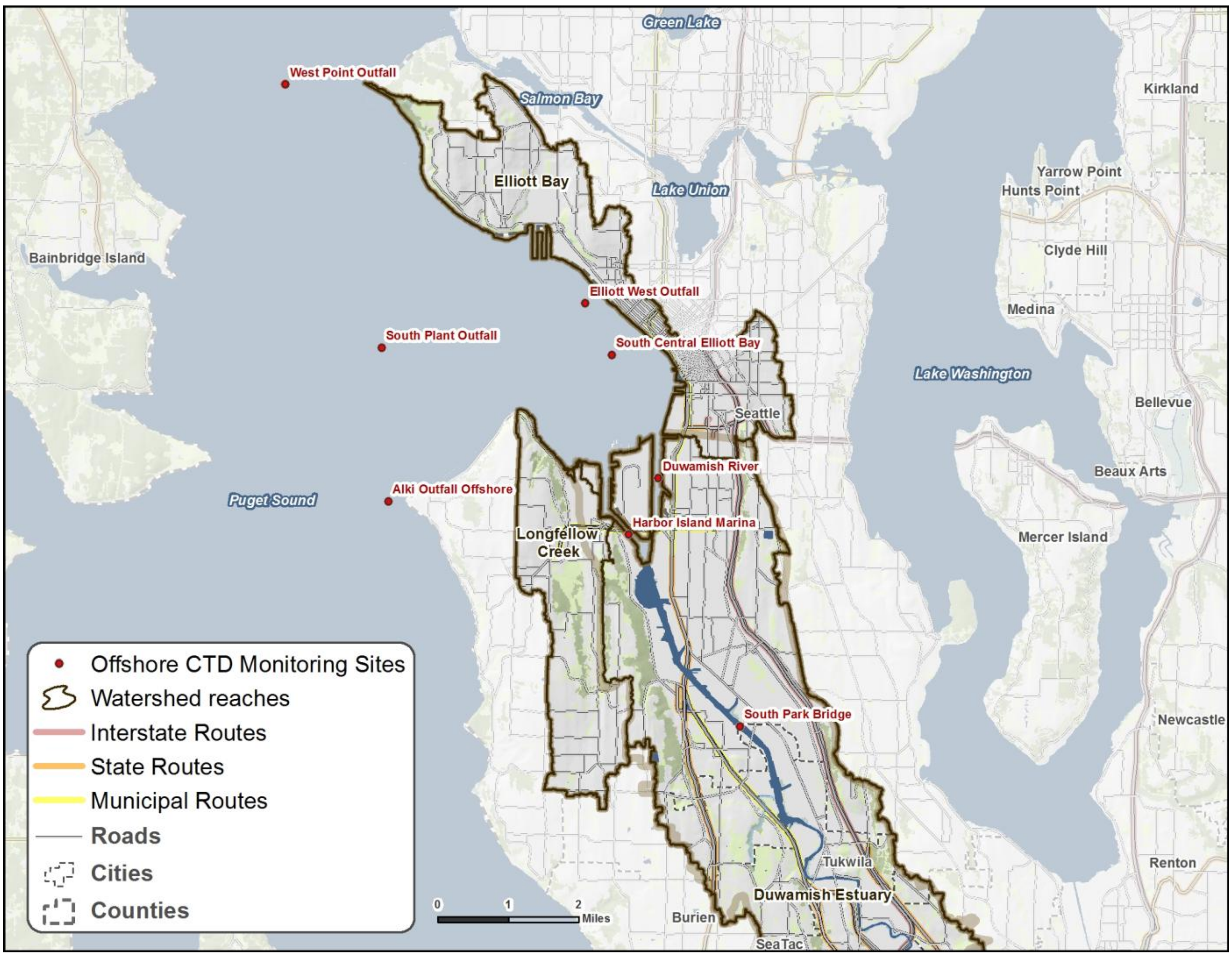

Figure 5-3. Offshore CTD monitoring sites of King County's Puget Sound Marine Monitoring Program

5.1.2 Supporting Data for Calibration of Hydrodynamics

For calibration of the hydrodynamic processes, data including velocity field, water surface elevations, salinity, and temperature are typically used when available. Water surface elevation data are available at NOAA tide station 9447130 at Seattle, which is very close to the open boundary locations, and the USGS station 12113350 on the Green River at Tukwila, WA, which is very close to the upstream boundary locations. These data can be used to mainly evaluate the tide and inflow influences on the water surface elevations at these two locations. Salinity and water temperature data will be the focus in the hydrodynamics calibration. Salinity and water temperature data located in the LDW will be used to support the hydrodynamics calibration. Data are available from 1998 to 2014 at the CTD sites as shown in Figure 5-3, and are sufficient to cover the entire modeling period, which will be a period within the recent 10 years.

In summary, boundary condition data for the hydrodynamic simulation of the LDW are sufficient to support the model configuration. The inputs with the highest uncertainty are the CSOs and the direct runoff from the drainage areas, which will be simulated using LSPC. Salinity and water temperature data are available to support the hydrodynamic model calibration.

5.2 WATER QUALITY MODEL CONFIGURATION AND CALIBRATION

Following hydrodynamic configuration and calibration, modeling of conventional water quality and fate and transport of contaminants can begin. The fate and transport of many contaminants are usually highly related to sediment transport with adsorption and desorption processes. DO, ammonia, and pH are related to organic carbon, organic nitrogen, nitrite-nitrate, phosphorus, and phytoplankton. The decomposition of benthic organic matter also contributes to oxygen demand and ammonia in the overlaying water column. Therefore, the sediment transport module needs to be activated in the EFDC to model the fate and transport of contaminants. The eutrophication module is needed for modeling the conventional water quality parameters on the 303(d) list, which includes carbon-nutrient-phytoplankton-DO-sediment diagenesis dynamics. The details of how the boundary conditions will be derived and the data for supporting calibration are presented below for each of the following: suspended sediment, dioxin/furan, arsenic, metals, other SVOCs, PAHs, PCBs, pesticides, phthalates, bacteria, and conventional water quality parameters including ammonia, DO, and pH.

5.2.1 Boundary Conditions and Calibration Data for Pollutants

The following section discusses the available pollutant data in the context of boundary and calibration data for the EFDC modeling components, and summarizes the suitability and approach for modeling by pollutant group.

5.2.1.1 Suspended Sediment/Solids

Suspended sediment/solids data are limited in the entire Green/Duwamish watershed (Table A-1). It will be assumed that the total suspended sediment/solids (TSS) will be mainly inorganic sediments. The LSPC model will be used to simulate TSS which will include three size classes of sediment: sand, silt, and clay. The LSPC model will be calibrated using TSS monitoring data from the Green River stations. In Elliott Bay, suspended sediment data are not available, but turbidity is monitored and can be used to inform suspended sediment concentrations at that boundary.

The TSS data in the LDW will be used for calibration of sediment transport modeling in EFDC.

5.2.1.2 Dioxin/Furan

The dioxin/furan listed in the LDW is 2,3,7,8 – TCDD. 2,3,7,8 – TCDD enters the water via air deposition, wash-off from contaminated land, and from waste disposal to the water. Once 2,3,7,8-TCDD is in water, most of it attaches to sediment particles and deposits on the sediment bed. However, a portion remains in the water column whether in dissolved state or in association with suspended/colloidal particles. Table A-2 shows that there were no ambient surface water data, nor any point source reporting of 2,3,7,8-TCDD. Air quality data and point source solids data are available, which can be used to estimate the mass loadings from air deposition and from point sources of 2,3,7,8-TCDD. The 2,3,7,8-TCDD data in the Green River watershed are very limited. With the limited data, multiple options will be applied to find the best way to represent the 2,3,7,8-TCDD from the watershed. If the limited data reveal that the levels are very low, a low level of 2,3,7,8-TCDD could be applied to the flows from the watershed. If no information is available to determine the levels of 2,3,7,8-TCDD from the watershed, the LSPC model cannot be calibrated and; therefore, levels of 2,3,7,8-TCDD from the watershed could also be estimated using the estuary data with iterations of model runs together with EFDC. Such calibration will not be as reliable and robust as the calibration when monitoring data are available. The wash-off of 2,3,7,8-TCDD from the combined sewer areas will be simulated in LSPC and the levels of 2,3,7,8-TCDD in the CSOs will be determined with a combination of monitoring data and LSPC results. No 2,3,7,8-TCDD data are available in the ambient surface water in Elliott Bay, and it will be determined if an assumption of low 2,3,7,8-TCDD levels are in the bay is appropriate unless new data are located.

The ambient surface sediment data and subsurface sediment data will be used to support the calibration of 2,3,7,8-TCDD processes in the LDW. The modeled 2,3,7,8 – TCDD concentrations will be compared against the observed data (need to be collected) to calibrate the partition coefficients and diffusion coefficients of 2,3,7,8 – TCDD in the sediment layer.

5.2.1.3 Arsenic

Arsenic data are available not only in LDW, but also in the Lower and Middle Green River watersheds (Table A-3). The LSPC model will simulate the yield of arsenic from various sources and pathways including air deposition, wash-off from contaminated land surfaces, and groundwater. In addition to the loadings associated with flow from the Green River watershed, the air quality and point source data in the LDW watershed will provide the direct air deposition and point source loadings of arsenic to the LDW. Arsenic from the combined sewer areas will be simulated in LSPC and the levels of arsenic in the CSOs will be determined with a combination of monitoring data and LSPC results. No arsenic data are available in the ambient surface water in Elliott Bay, and it can be assumed that arsenic levels are low in the bay unless new data are located.

The ambient surface water data and ambient surface sediment will be used to support the calibration of the arsenic dynamics in LDW. The modeled arsenic concentrations will be compared against the observed data to calibrate the partition coefficients and diffusion coefficients of arsenic in the sediment layer. This comparison will also assess the need for more complex speciation modeling for describing arsenic transport and transformation.

5.2.1.4 Metals

Metals that need to be addressed in LDW include cadmium, chromium, copper, lead, mercury, silver, and zinc. Metals data are summarized in Tables A-4, A-5, A-6, A-7, A-8, A-9, and A-10. Metals data in ambient surface water are available in the Lower Green River and Middle Green River watersheds, and the LSPC model will be used to calibrate the metals wash-off from the land surface and the fate and transport of metals in the rivers. LSPC model results of metals will be used to represent the loadings of metals associated with the boundary conditions from Green River and Black River. Air quality data and point source data are available in the LDW subwatershed and these data will be processed to provide external loadings of metals from air deposition and point sources. Metals from the combined sewer areas will be simulated in LSPC and the levels of metals in the CSOs will be determined with a combination of monitoring data and LSPC results. No metals data are available in the ambient surface water in Elliott Bay, and it will be assumed that metals are low in the bay unless new data are located. No ambient water data are available for all of these metals during recent time periods in LDW to support the calibration. Historical ambient water data are available and these data can be used to evaluate the magnitudes of the modeled metals.

Data for metals in ambient surface sediment are available and these data will support the calibration of the processes of metals including adsorption, desorption, settling and resuspension together with sediment transport. The modeled metal concentrations will be compared against the observed data to calibrate the partition coefficients and diffusion coefficients of metals in the sediment layer, and assess the need for complex speciation modeling.

5.2.1.5 Other SVOCs

Other SVOCs that need to be addressed in LDW include 4-methylphenol, benzoic acid, dibenzofuran, and phenol. Other SVOC data are summarized in Tables A-11, A-12, A-13, and A-14. No data in ambient surface water are available in recent years in the entire Green/Duwamish Watershed. The LSPC model will be only able to calibrate the other SVOCs using the ambient surface sediment data. LSPC SVOC model results of other SVOCs will be used to represent the loadings of SVOCs associated with the boundary conditions from Green River and Black River. Air quality data are not available. Point source data are available in the LDW subwatershed. Other SVOCs from the combined sewer areas will be simulated in LSPC and the levels of other SVOCs in the CSOs will be determined with a combination of monitoring data and LSPC results. No other SVOCs data are available in the ambient surface water in Elliott Bay, and it will be assumed that other SVOCs levels are low in the bay unless new data are located.

No ambient water data are available for other SVOCs during recent time periods in the LDW to support the calibration. Historical ambient water data are available and these data can be used to evaluate the magnitudes of the modeled other SVOCs. Other SVOC data in ambient surface sediment are available and these data will support the calibration of the processes of other SVOCs including adsorption, desorption, settling and resuspension together with sediment transport. The modeled SVOCs will be compared against the observed data to calibrate the partition coefficients and diffusion coefficients of SVOCs in the sediment layer.

5.2.1.6 PAHs

There are 19 different PAHs that are on the 303(d) list for the LDW. Modeling all 19 PAHs is not advisable given the required effort. Some of the PAHs behave similarly and others do not; this behavior is closely associated with molecular weight of the individual PAH. They can be grouped into several (presumably 2 to 4) groups during model development (Note: this will be explored in more detail in a follow-on memo). In this memo, the data for all PAHs are lumped together to evaluate if data are sufficient to support the configuration and calibration of PAHs (Table A-15). PAHs data are available, with additional collection ongoing, in ambient surface water and ambient surface sediment in the Lower Green and Middle Green Watersheds. The LSPC model will be calibrated using these data and the LSPC model results of PAHs will be used to represent the loadings of PAHs associated with the boundary conditions from the Green River and Black River. Air quality and point source data are also available. PAHs loadings from air deposition and point sources will be represented in the LDW EFDC model. PAHs from the combined sewer areas will be simulated in LSPC and the levels of PAHs in the CSOs will be determined with a combination of monitoring data and LSPC results. No PAHs data are available in the ambient surface water in Elliott Bay, and it will be assumed that PAHs levels are low in the bay unless new data are located.

Ambient surface water and ambient surface sediment data are both available during recent time periods in LDW to support the calibration. The modeled PAHs will be compared against the observed data to calibrate the partition coefficients and diffusion coefficients of PAHs in the sediment layer.

5.2.1.7 PCBs

Table A-16 presents all the data for PCBs, which have been grouped for the purposes of this analysis similar to PAHs. PCBs data are available in ambient surface water and ambient surface sediment in the Lower Green and Middle Green Watersheds. The LSPC model will be calibrated using these data and the LSPC model results of

PCBs will be used to represent the loadings of PCBs associated with the boundary conditions from the Green River and Black River. Air quality and point source data are also available. PCBs loadings from air deposition and point sources will be represented in the LDW EFDC model. PCBs from the combined sewer areas will be simulated in LSPC and the levels of PCBs in the CSOs will be determined with a combination of monitoring data and LSPC results. No PCBs data are available in the ambient surface water in Elliott Bay, and it will be assumed that PCBs levels in the bay are in equilibrium with surface sediment concentrations unless new data are located, or PCBs will be assumed to be low.

Ambient surface water and ambient surface sediment data are both available during recent time periods in LDW to support the calibration. The modeled PCBs concentrations will be compared against the observed data to calibrate the partition coefficients and diffusion coefficients of PCBs in the sediment layer.

5.2.1.8 Pesticides

Pesticides that need to be addressed in the LDW include 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, alpha-BHC, and dieldrin. Pesticides data are summarized in Tables A-17, A-18, A-19, A-20, and A-21. Among these pesticides, limited ambient surface water data are only available for dieldrin from the Middle Green River. The LSPC model will be only able to calibrate pesticides using the ambient surface sediment data. LSPC model results of pesticides will be used to represent the loadings of pesticides associated with the boundary conditions from Green River and Black River. No air deposition data are available. Point source data are available in the Duwamish Estuary subwatershed. Pesticides from the combined sewer areas will be simulated in LSPC and the levels of pesticides in the CSOs will be determined with a combination of monitoring data and LSPC results. No pesticides data are available in the ambient surface water in Elliott Bay, and it will be assumed that pesticides levels are low in the bay unless new data are located.

Ambient surface water data are very limited for 4,4'-DDD, 4,4'-DDT, and alpha-BHC. Calibration of these pesticides will focus on using the ambient surface sediment data. Ambient surface water data for 4,4'-DDE and dieldrin are available more than for the other three pesticides. Calibration of these two pesticides can use the data from both ambient surface water and ambient surface sediment. The modeled pesticides will be compared against the observed data to calibrate the partition coefficients and diffusion coefficients of pesticides in the sediment layer.

5.2.1.9 Phthalates

Phthalates that need to be addressed in the LDW include bis(2-ethylhexyl) phthalate, butyl benzyl phthalate, dibutyl phthalate, dimethyl phthalate, and di-n-octyl phthalate. Phthalate data were grouped and summarized in Table A-22. No ambient surface water data are available in the Green River Watershed. The LSPC model will be only able to calibrate phthalates using the ambient surface sediment data. LSPC model results of phthalates will be used to represent the loadings of phthalates associated with the boundary conditions from Green River and Black River. No air quality data are available. Point source data are available in the LDW subwatershed. Phthalates from the combined sewer areas will be simulated in LSPC and the levels of phthalates in the CSOs will be determined with a combination of monitoring data and LSPC results. No phthalates data are available in the ambient surface water in Elliott Bay, and it will be assumed that phthalates levels are low in the bay unless new data are located.

No recent ambient surface water data are available for phthalates. Calibration of these pesticides will focus on using the ambient surface sediment data. Historical phthalates data will be used to evaluate the magnitudes of modeled phthalates. The modeled phthalates will be compared against the observed data to calibrate the partition coefficients and diffusion coefficients of phthalates in the sediment layer.

5.2.1.10 Bacteria

Bacteria data are available not only in LDW, but also in the Lower, Middle, and Upper Green River watersheds (Table A-23). The LSPC model can simulate the wash-off of bacteria from various land surfaces, and contributions from groundwater. It is not expected that air is a source of bacteria. The bacteria data from point sources are available but limited, and will be used to estimate bacteria concentrations from point source and CSOs. A total of 1,253 bacteria samples at 20 stations were collected from 2003 to 2010 in Elliott Bay. These data will be processed to serve as the open boundary conditions of bacteria.

The ambient surface water data will be used to support the calibration of the bacteria modeling in LDW.

5.2.1.11 Conventional Water Quality Parameters

The water quality model for the conventional parameters on the 303(d) list will simulate eutrophication processes incorporated with a dynamic sediment diagenesis module to support the tracking of deposition and decomposition of organic matter on the sediment bed. To configure the water quality model, data for the listed parameters as well as other related parameters are needed. These data include dissolved oxygen, nitrite/nitrate, organic nitrogen, orthophosphate, organic phosphorus, organic carbon, and phytoplankton/chlorophyll *a* (Tables A-24, A-25, A-26, A-27, A-28, A-29, and A-30). The LSPC model will simulate these parameters and provide inputs to the EFDC model. Conventional water quality parameters in the CSOs will be determined with a combination of monitoring data and LSPC results.

In addition to carbon, oxygen, nutrients, and phytoplankton loadings from the upland watershed associated with the boundary conditions of Green River and Black River, the levels of carbon, oxygen, and nutrients in Elliott Bay at the open boundary locations are needed as inputs to the model. The King County Offshore CTD monitoring sites provide data for dissolved oxygen and chlorophyll *a*. No data are available for other parameters at the CTD sites. TP data are only available from 1973 to 1987. Ammonia data are available from 2006 to 2008 with a total of 254 samples at five monitoring stations. Limited chlorophyll *a* data are available from 2006 to 2008 with a total of 111 samples. Organic nitrogen, organic phosphorus, and organic carbon data are not available in Elliott Bay. Orthophosphate data are limited with only 20 samples in recent years. Nitrite/nitrate samples are available with a total of 254 samples in recent years.

The Salish Sea Model developed by Pacific Northwest National Laboratory (PNNL) covers the entire Puget Sound and models water quality with a focus on nutrient-DO interactions. Its model results can be extracted to use as the open boundary conditions for the parameters without direct monitoring data. For the parameters with limited data availability, the model results can be used to fill the data gaps.

pH is related to carbon dioxide in the water, which is influenced by water temperature and the photosynthesis and respiration processes of aquatic plants. Available pH data are shown in Table A-31. In addition to water temperature and causes related to aquatic plants, pH may be affected by loadings of acidic and alkaline constituents. It is not clear what the major causes are for the pH impairments in the LDW. The current EFDC model does not include pH. It can be modified to include pH if the major cause is due to aquatic plants. If external loading of acidic and alkaline constituents is a major cause, the EFDC model would require significant updates to include the necessary transport features.

6.0 DATA FOR FOOD WEB MODEL CONFIGURATION AND CALIBRATION

The food web model will simulate the bioaccumulation of contaminants on the 303(d) list as shown in Table 6-1. The EFDC model will simulate the fate and transport of these contaminants in the LDW. The food web model will use the results from the EFDC model for both the environmental conditions such as salinity and water temperature and the levels of contaminants.

The calibration of the food web model requires contaminant concentration data in tissues. Table 6-1 lists the available data to support the calibration of the bioaccumulation processes in the LDW. Among all the contaminants, only 13 recent tissue data are available for 2,3,7,8-TCDD. It is expected that the bio-accumulation of 2,3,7,8-TCDD will be minimally calibrated. All other contaminants have sufficient recent data to support calibration of the bioaccumulation processes in the food web model.

Table 6-1. Parameters listed for tissue impairment

Parameters on 303(d)	Impaired Media	All Tissue Quality Data	Recent Tissue Quality Data
2,3,7,8-TCDD	5T	17	13
Arsenic	5T	464	328
PAHs	5T	453	296
PCB	5T	934	466
4,4'-DDD	5T	554	311
4,4'-DDE	5T	557	311
4,4'-DDT	5T	548	311
Alpha-BHC	5T	504	312
Dieldrin	5T	535	312
Phthalates	5T	422	304

7.0 ONGOING DATA COLLECTION

Several important data collection efforts are underway in the watershed. A brief summary of these efforts is provided below. The additional data collected under these studies will provide important data for water quality calibration, especially the watershed model.

USGS completed initial phases of a study on the Green River and Lower Duwamish Waterway which involved water and sediment sampling during periods of variable flow conditions in 2013 (Conn and Black, 2014). Sampling occurred at a single strategic location, at river kilometer 16.7 from the bridge over the Duwamish River at Golf Course at Tukwila, Washington (USGS gage 12113390). Samples were taken at seven sampling periods: five were during periods of low precipitation, and two were collected during the rising limb and peak flow of a single storm event in April, 2013. Samples of whole water, suspended sediment, and bed sediment were analyzed for a large suite of compounds: temperature, pH, DO, specific conductance, turbidity, dioxins/furans (12 constituents), biphenyls (17 constituents), hexavalent chromium, polycyclic aromatic hydrocarbons (12 constituents), PCBs (>200 constituents), arsenic, barium, chromium, copper, lead, nickel, vanadium, zinc, total organic carbon, particle size. All six boat-based bed-sediment sampling periods occurred during relatively dry periods. Sediment and chemical loads were estimated based on sampling, with the highest loads occurring during storm-peak sampling.

The USGS sediment sampling and analysis discussed in Conn and Black (2014) will continue until at least June, 2015 (personal communication with Ronald Timm, WA Ecology). A new data report will be compiled around June 2015 to encompass the ongoing 2013-2015 sampling period, which may be extended until June, 2017 if funding permits. Estimates of chemical loads along the Green River and Lower Duwamish Waterway are expected to be produced when field work is completed. Additional sediment loading data for PCBs from the Green River to the LDW has been collected by Ecology (https://fortress.wa.gov/ecy/publications/summarypages/0903028.html).

King County is conducting a study of suspended solids and pollutants along the Green River mainstem (at Flaming Geyser State Park, and Foster Links Golf Course), and four major tributaries (Soos Creek, Mill Creek, Newaukum Creek, and Black River). A sampling analysis plan provides information about the effort (King County, 2013a). The project involves storm sampling of analytes including arsenic, cadmium, chromium, copper, lead, nickel, silver, vanadium, zinc, PAHs/semi-volatile organic compounds, PCBs, dioxins/furans, mercury, total organic carbon, total solids, total suspended solids, particle size distribution. Sampling efforts expected at every location entail: one dry season base flow sample and five wet season/storm flow samples of filtered solids, and two sediment trap samples. The report and analysis of this sampling effort is expected to be completed in March, 2015. Related work is described in King County (2013b) and King County (2014).

Finally, a current multi-year PCB research and development project being conducted by MIT and the US Army Corps of Engineers (USACE), concerns the development of a mass balance model for contaminated sediments in the LDW (Gschwend et al., 2014). The model will be based on one source term (diffusion from bed sediments) and one sink (flushing). The concentration gradient in the bed-water zone will be determined from hydrodynamic information to assess boundary layer thickness and the use of passive (PE) passive samplers to characterize the freely dissolved overlying water concentration.

The goals for the USACE research project are to develop the sampler for low solubility contaminants (PCBs, PAHs) and use the result to assess the accuracy of the mass balance model. Additional goals include using the samplers to map groundwater input zones within sediments and assess episodic, short-lived sources including CSOs and storm drain discharges (potential fingerprinting). Once the mass balance model and passive samplers are developed, they will be integrated with a food web model to examine if the model uptake is consistent with measured uptake and accumulation. The researchers will examine if a more refined exposure field, as determined from the PE samplers, can lead to improvements in food web models. Results should be useful for the PLA and modeling activity for the groups of low solubility contaminants, such as PCBs and PAHs that consist of numerous contaminants that could be more efficiently modeled as groups of similarly behaving contaminants. For example, the research will examine if a mixture of PCBs could be handled as compounds with a single property rather than many congeners. Use of the research for the PLA will depend on when results can be made available.

8.0 SUMMARY

LSPC and EFDC Hydrology Data. Model configuration and calibration to predict water movement (i.e., hydrology and hydrodynamics) is the first step in model development. The models will be built utilizing the existing HSPF and EFDC models as a starting point. Supporting data for configuration and calibration of hydrology are generally available and are not expected to be an obstacle for model development.

LSPC and EFDC Water Quality Data. Water quality pollutant data were evaluated for both LSPC and EFDC configuration and calibration. In general, LSPC can be configured to model pollutants with potency factors, build-up/wash-off, and in-stream transport. The EFDC model will simulate the fate and transport of contaminants and conventional water quality parameters in the LDW. Data are available to support LSPC and EFDC configuration and calibration, to different degrees. Calibration data are sufficiently available for some parameters, but are limited for others. The additional data being collected by USGS, Ecology, King County, and the Army Corps will be important supplements to the available data, and the modeling time period should incorporate this data as appropriate (i.e., at least through a significant portion of 2015). In addition, data from sources such as the Puget Sound toxics studies on loading from source types (e.g., Ecology and King County, 2011; Herrera Environmental Consultants, 2007) will be valuable to constrain the models.

Elliott Bay data were examined to support the configuration of open boundary conditions for EFDC. Limited data have been located to date for the contaminants in ambient surface water in Elliott Bay. Therefore, assumptions regarding the levels of the contaminants in the bay may be needed if data are not available.

LSPC and EFDC Model Configuration. Existing models provide an important line of information and will be examined in detail prior to model development (these models have not been compiled for the PLA to date). The CSO information will rely on King County data and models. Input files for the previous HSPF and EFDC models (and potentially CE-QUAL-W2) will be extracted and compared to monitoring data to determine the most reasonable representations of the boundary conditions to support model configuration.

The assessment conducted to date suggests there are considerable data available to support model development; however, a number of data gaps will need to be filled. For example, a number of data sources are available on a limited collection frequency. For such data, different approaches may be applied in the modeling environment to interpolate or extrapolate the limited available data to cover the entire modeling period. Multiple options are available to fill these type of data gaps for model configuration.

In an upcoming "Data Gap and Pollutant Groupings" memo, data will be reviewed further to identify data gaps and recommend strategies for filling them. This memo will include a set of protocols and decision criteria for filling gaps that can be incorporated into a Quality Assurance Project Plan (QAPP). These recommendations will take into account the decisions that need to be made with the models, and the additional information needed to inform those decisions.

In addition to data gaps, the significant numbers of impairments poses a challenge for model development in terms of time and cost. The next memo will address ways in which the pollutants can be prioritized. Finally, the next memo will analyze pollutant groupings with a focus on parameters such as PCBs, PAHs, and phthalates to determine the most appropriate way to evaluate them given the large numbers of individual compounds with potential groupings (i.e. homolog groups for PCBs, high or low molecular weight groups for PAHs) based on similarities in contaminant adsorption, solubility, degradation rates, or other key properties.

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APPENDIX A

Table A-1. TSS data in Green/Duwamish Watershed

TSS Summary Table								
Waterbody/Watershed	Ambient Surface Water Data (2001-2012)		Point Source Reporting (2009-2011)		Ambient Surface Sediment (1978-2011)		Point Source Solids (1989-2012)	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary (i.e., LDW)	1	21	16	46	85	977	8	76
Lower Green River	4	96	0	0	18	604	0	0
Middle Green River	3	28	0	0	34	740	2	20
Upper Green River	0	0	0	0	1	4	0	0
Recent Data (10 Years)	(2001-2012)		(2009-2011)		(1999-2011)		(2009-2012)	
Duwamish Estuary	1	21	16	46	58	409	8	76
Lower Green River	4	96	0	0	12	396	0	0
Middle Green River	3	28	0	0	10	439	0	0
Upper Green River	0	0	0	0	1	4	0	0

Table A-2. Dioxin/Furan data in Green/Duwamish Watershed

Dioxin / Furan Summary Table																
Waterbody /Watershed	Ambient Surface Water No Data		Point Source Reporting No Data		Groundwater Quality (2008-2010)		Ambient Surface Sediment (1989-2012)		Point Source Solids (2009-2011)		Subsurface Sediment (2006-2012)		Tissue Quality (1991-2007)		Air Quality (2011-2012)	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	0	0	0	0	6	8	363	729	78	102	86	120	5	17	3	26
Lower Green River	0	0	0	0	0	0	4	5	0	0	0	0	0	0	2	17
Middle	0	0	0	0	0	0	3	3	0	0	0	0	2	4	0	0

Dioxin / Furan Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	No Data		No Data		(2008-2010)		(1989-2012)		(2009-2011)		(2006-2012)		(1991-2007)		(2011-2012)	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Green River																
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	0	0	0	0	6	8	370	737	78	102	86	120	7	21	5	43
Recent Data	No Data		No Data		(2008-2010)		(2004-2012)		(2009-2011)		(2006-2012)		(2006-2007)		(2011-2012)	
Duwamish Estuary	0	0	0	0	6	8	295	633	78	102	86	120	4	13	3	26
Lower Green River	0	0	0	0	0	0	4	5	0	0	0	0	0	0	2	17
Middle Green River	0	0	0	0	0	0	3	3	0	0	0	0	2	4	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	0	0	0	0	6	8	302	641	78	102	86	120	6	17	5	43

Table A-3. Arsenic data in Green/Duwamish Watershed

Arsenic Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1995-2012)		(2004-2012)		(2000-2011)		(1980-2012)		(1998-2012)		(1990-2012)		(1984-2007)		(2011-2012)	
	Stations	Samples	Station	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	10	413	40	272	272	1,630	2,205	2,998	1,170	1,590	341	585	321	464	3	72
Lower Green River	10	144	0	0	46	406	47	48	0	0	0	0	0	0	2	32
Middle Green River	11	87	0	0	0	0	41	43	0	0	0	0	2	2	0	0
Upper	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0

Arsenic Summary Table																
Waterbody /Watershed	Ambient Surface Water (1995-2012)		Point Source Reporting (2004-2012)		Groundwater Quality (2000-2011)		Ambient Surface Sediment (1980-2012)		Point Source Solids (1998-2012)		Subsurface Sediment (1990-2012)		Tissue Quality (1984-2007)		Air Quality (2011-2012)	
	Stations	Samples	Station	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Green River																
All Data	31	644	40	272	318	2,036	2,294	3,090	1,170	1,590	341	585	324	467	5	104
Recent Data	(2001-2012)		(2004-2012)		(2002-2011)		(1995-2012)		(2002-2012)		(2003-2012)		(2003-2007)		(2011-2012)	
Duwamish Estuary	1	21	40	272	270	1,628	891	1,205	1,155	1,574	209	388	301	328	3	72
Lower Green River	9	143	0	0	46	406	23	23	0	0	0	0	0	0	2	32
Middle Green River	7	81	0	0	0	0	36	37	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	17	245	40	272	316	2,034	950	1,265	1,155	1,574	209	388	301	328	5	104

Table A-4. Cadmium data in Green/Duwamish Watershed

Cadmium Summary Table																
Waterbody /Watershed	Ambient Surface Water (1992-2007)		Point Source Reporting (2004-2012)		Groundwater Quality (2000-2011)		Ambient Surface Sediment (1980-2012)		Point Source Solids (1998-2011)		Subsurface Sediment (1990-2012)		Tissue Quality (1984-2006)		Air Quality (2011-2012)	
	Stations	Samples	Station	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	9	403	42	300	175	1,290	2,130	2,870	461	495	391	712	301	380	3	72
Lower Green River	7	62	0	0	13	53	47	54	0	0	0	0	0	0	2	32
Middle Green River	10	81	0	0	0	0	41	59	0	0	0	0	2	2	0	0
Upper Green River	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0

Cadmium Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1992-2007)		(2004-2012)		(2000-2011)		(1980-2012)		(1998-2011)		(1990-2012)		(1984-2006)		(2011-2012)	
	Stations	Samples	Station	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
All Data	26	546	42	300	188	1,343	2,219	2,984	461	495	391	712	304	383	5	104
Recent Data	(1995-2007)		(2004-2012)		(2002-2011)		(1995-2012)		(2008-2011)		(2003-2012)		(2003-2006)		(2011-2012)	
Duwamish Estuary	0	0	42	300	173	1,288	815	1,118	454	487	250	488	286	296	3	72
Lower Green River	5	44	0	0	13	53	22	22	0	0	0	0	0	0	2	32
Middle Green River	5	58	0	0	0	0	36	37	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	10	102	42	300	186	1,341	873	1,177	454	487	250	488	286	296	5	104

Table A-5. Chromium data in Green/Duwamish Watershed

Chromium Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1991-2007)		(2004-2012)		(2000-2011)		(1981-2012)		(1998-2011)		(1994-2012)		(1984-2004)		(2011-2012)	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	9	381	40	272	204	1,352	1,899	2,571	459	493	326	645	299	366	3	72
Lower Green River	6	45	0	0	19	67	47	54	0	0	0	0	0	0	2	32
Middle Green River	6	59	0	0	0	0	41	59	0	0	0	0	2	2	0	0
Upper Green River	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0
All Data	21	485	40	272	223	1,419	1,988	2,685	459	493	326	645	302	369	5	104
Recent	(1995-2007)		(2004-2012)		(2002-2011)		(1995-2012)		(2008-2011)		(2003-2012)		(2003-2004)		(2011-2012)	

Chromium Summary Table

Waterbody /Watershed	Ambient Surface Water (1991-2007)		Point Source Reporting (2004-2012)		Groundwater Quality (2000-2011)		Ambient Surface Sediment (1981-2012)		Point Source Solids (1998-2011)		Subsurface Sediment (1994-2012)		Tissue Quality (1984-2004)		Air Quality (2011-2012)	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Data																
Duwamish Estuary	0	0	40	272	202	1,350	815	1,135	452	485	250	489	285	294	3	72
Lower Green River	5	44	0	0	19	67	22	22	0	0	0	0	0	0	2	32
Middle Green River	5	58	0	0	0	0	36	37	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	10	102	40	272	221	1,417	873	1,194	452	485	250	489	285	294	5	104

Table A-6. Copper data in Green/Duwamish Watershed

Copper Summary Table

Waterbody /Watershed	Ambient Surface Water (1992-2009)		Point Source Reporting (2004-2012)		Groundwater Quality (2000-2011)		Ambient Surface Sediment (1981-2012)		Point Source Solids (1998-2012)		Subsurface Sediment (1990-2012)		Tissue Quality (1984-2004)		Air Quality (2011-2012)	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	9	392	38	296	144	1,209	2,192	3,011	1,135	1,555	391	713	304	428	3	72
Lower Green River	8	301	0	0	12	47	49	56	0	0	0	0	0	0	2	32
Middle Green River	10	222	0	0	0	0	41	59	0	0	0	0	2	2	0	0
Upper Green River	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0
All Data	27	915	38	296	156	1,256	2,283	3,127	1,135	1,555	391	713	307	431	5	104
Recent Data	(1995-2009)		(2004-2012)		(2002-2011)		(1995-2012)		(2002-2012)		(2003-2012)		(2003-2004)		(2011-2012)	
Duwamish Estuary	0	0	38	296	142	1,207	879	1,216	1,120	1,539	250	489	285	294	3	72

Copper Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1992-2009)		(2004-2012)		(2000-2011)		(1981-2012)		(1998-2012)		(1990-2012)		(1984-2004)		(2011-2012)	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Lower Green River	6	283	0	0	12	47	23	23	0	0	0	0	0	0	2	32
Middle Green River	5	199	0	0	0	0	36	37	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	11	482	38	296	154	1,254	938	1,276	1,120	1,539	250	489	285	294	5	104

Table A-7. Lead data in Green/Duwamish Watershed

Lead Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1992-2007)		(2004-2012)		(1992-2011)		(1980-2012)		(1998-2012)		(1990-2012)		(1984-2006)		(2011-2012)	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	9	397	42	300	291	1,767	2,199	3,014	1,174	1,589	391	718	305	432	3	72
Lower Green River	7	62	0	0	162	870	48	55	0	0	0	0	0	0	2	32
Middle Green River	10	77	0	0	27	281	41	59	0	0	0	0	2	2	0	0
Upper Green River	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0
All Data	26	536	42	300	480	2,918	2,289	3,129	1,174	1,589	391	718	308	435	5	104
Recent Data	(2002-2007)		(2004-2012)		(1992-2011)		(1995-2012)		(2002-2012)		(2003-2012)		(2003-2006)		(2011-2012)	
Duwamish Estuary	0	0	42	300	287	1,763	880	1,214	1,159	1,573	250	494	286	296	3	72
Lower Green River	5	44	0	0	153	851	23	23	0	0	0	0	0	0	2	32

Lead Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1992-2007)		(2004-2012)		(1992-2011)		(1980-2012)		(1998-2012)		(1990-2012)		(1984-2006)		(2011-2012)	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Middle Green River	4	53	0	0	22	241	36	37	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	9	97	42	300	462	2,855	939	1,274	1,159	1,573	250	494	286	296	5	104

Table A-8. Mercury data in Green/Duwamish Watershed

Mercury Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1995-2007)		(2004-2012)		(2000-2011)		(1998-2012)		(1988-2012)		(1990-2012)		(1984-2006)		(2011-2012)	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	9	30	37	289	163	1,240	2,213	2,988	1,052	1,423	387	757	338	471	3	72
Lower Green River	7	50	0	0	12	47	47	54	0	0	0	0	0	0	2	32
Middle Green River	8	65	0	0	0	0	45	65	0	0	0	0	5	25	0	0
Upper Green River	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0
All Data	24	145	37	289	175	1,287	2,306	3,108	1,052	1,423	387	757	344	497	5	104
Recent Data	(2002-2007)		(2004-2012)		(2002-2011)		(1995-2012)		(2002-2012)		(2003-2012)		(1995-2006)		(2011-2012)	
Duwamish Estuary	0	0	37	289	161	1,238	909	1,237	1,036	1,406	246	533	285	293	3	72
Lower Green River	5	42	0	0	12	47	22	22	0	0	0	0	0	0	2	32
Middle Green River	5	60	0	0	0	0	37	40	0	0	0	0	4	24	0	0

Mercury Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1995-2007)		(2004-2012)		(2000-2011)		(1998-2012)		(1988-2012)		(1990-2012)		(1984-2006)		(2011-2012)	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	10	102	37	289	173	1,285	968	1,299	1,036	1,406	246	533	289	317	5	104

Table A-9. Silver data in Green/Duwamish Watershed

Silver Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1996-2007)		(2004-2012)		(2000-2011)		(1980-2012)		(1998-2011)		(1990-2012)		(1995-2004)		(2011-2012)	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	8	404	39	271	136	466	1,996	2,679	463	502	391	712	299	381	3	72
Lower Green River	5	44	0	0	12	47	46	47	0	0	0	0	0	0	2	32
Middle Green River	4	53	0	0	0	0	39	40	0	0	0	0	2	2	0	0
Upper Green River	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0
All Data	17	501	39	271	148	513	2,082	2,767	463	502	391	712	302	384	5	104
Recent Data	(2002-2007)		(2004-2012)		(2004-2011)		(1995-2012)		(2008-2011)		(2003-2012)		(2003-2004)		(2011-2012)	
Duwamish Estuary	0	0	39	271	134	464	780	1,056	456	494	250	488	284	293	3	72
Lower Green River	5	44	0	0	12	47	22	22	0	0	0	0	0	0	2	32
Middle Green River	4	53	0	0	0	0	36	37	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	9	97	39	271	146	511	838	1,115	456	494	250	488	284	293	5	104

Table A-10. Zinc data in Green/Duwamish Watershed

Zinc Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1992-2007)		(2004-2012)		(2000-2011)		(1981-2012)		(1998-2012)		(1990-2012)		(1984-2004)		(2011-2012)	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	9	403	38	296	154	1,239	2,187	2,947	1,132	1,547	391	712	299	377	3	72
Lower Green River	8	224	0	0	12	47	48	55	0	0	0	0	0	0	2	32
Middle Green River	10	85	0	0	0	0	41	59	0	0	0	0	2	2	0	0
Upper Green River	1	4	0	0	0	0	1	1	0	0	0	0	1	1	0	0
All Data	28	716	38	296	166	1,286	2,277	3,062	1,132	1,547	391	712	302	380	5	104
Recent Data	(1995-2007)		(2004-2012)		(2002-2011)		(1995-2012)		(2002-2012)		(2003-2012)		(2003-2004)		(2011-2012)	
Duwamish Estuary	0	0	38	296	152	1,237	879	1,200	1,117	1,531	250	488	284	293	3	72
Lower Green River	6	206	0	0	12	47	23	23	0	0	0	0	0	0	2	32
Middle Green River	5	62	0	0	0	0	36	37	0	0	0	0	0	0	0	0
Upper Green River	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	12	272	38	296	164	1,284	938	1,260	1,117	1,531	250	488	284	293	5	104

Table A-11. 4-Methylphenol data in Green/Duwamish Watershed

4-Methylphenol Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1996-1997)		(2004-2012)		(2004-2011)		(1982-2012)		(2002-2012)		(1990-2012)		(1991-2004)		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	8	94	30	166	161	589	1,917	2,463	819	1,150	329	583	300	407	0	0
Lower Green River	0	0	0	0	22	25	6	6	0	0	0	0	0	0	0	0
Middle Green River	0	0	0	0	0	0	23	23	0	0	0	0	0	0	0	0
Upper	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0

4-Methylphenol Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1996-1997)		(2004-2012)		(2004-2011)		(1982-2012)		(2002-2012)		(1990-2012)		(1991-2004)		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Green River																
All Data	8	94	30	166	183	614	1,947	2,493	819	1,150	329	583	300	407	0	0
Recent Data	No Data		(2002-2012)		(2004-2011)		(2003-2012)		(2002-2012)		(2003-2012)		(2004)		No Data	
Duwamish Estuary	0	0	30	166	161	589	771	1,027	810	1,141	203	405	284	291	0	0
Lower Green River	0	0	0	0	22	25	5	5	0	0	0	0	0	0	0	0
Middle Green River	0	0	0	0	0	0	22	22	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	0	0	30	166	183	614	798	1,054	810	1,141	203	405	284	291	0	0

Table A-12. Benzoic Acid data in Green/Duwamish Watershed

Benzoic Acid Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1996-1997)		(2004-2012)		(2004-2011)		(1982-2012)		(2002-2012)		(1990-2012)		(1991-2004)		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	8	94	27	149	174	631	1,810	2,299	817	1,148	329	582	300	407	0	0
Lower Green River	0	0	0	0	22	25	22	22	0	0	0	0	0	0	0	0
Middle Green River	0	0	0	0	0	0	35	35	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	8	94	27	149	196	656	1,867	2,356	817	1,148	329	582	300	407	0	0
Recent Data	No Data		(2004-2012)		(2004-2011)		(2003-2012)		(2002-2012)		(2003-2012)		(2004)		No Data	
Duwamish Estuary	0	0	27	149	174	631	782	1,046	808	1,139	203	404	284	291	0	0
Lower Green River	0	0	0	0	22	25	22	22	0	0	0	0	0	0	0	0

Benzoic Acid Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1996-1997)		(2004-2012)		(2004-2011)		(1982-2012)		(2002-2012)		(1990-2012)		(1991-2004)		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Middle Green River	0	0	0	0	0	0	35	35	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	0	0	27	149	196	656	839	1,103	808	1,139	203	404	284	291	0	0

Table A-13. Dibenzofuran data in Green/Duwamish Watershed

Dibenzofuran Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1996-1997)		(2004-2012)		(2004-2011)		(1982-2012)		(2002-2012)		(1990-2012)		(1992-2004)		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	8	94	31	240	227	994	2,064	2,649	823	1,174	316	551	300	409	0	0
Lower Green River	0	0	0	0	43	323	41	42	0	0	0	0	0	0	0	0
Middle Green River	0	0	0	0	0	0	35	35	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	8	94	31	240	270	1,317	2,140	2,726	823	1,174	316	551	300	409	0	0
Recent Data	No Data		(2004-2012)		(2004-2011)		(2003-2012)		(2002-2012)		(2003-2012)		(2003-2004)		No Data	
Duwamish Estuary	0	0	31	240	227	994	862	1,153	814	1,165	190	373	285	292	0	0
Lower Green River	0	0	0	0	43	323	23	23	0	0	0	0	0	0	0	0
Middle Green River	0	0	0	0	0	0	35	35	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	0	0	31	240	270	1,317	920	1,211	814	1,165	190	373	285	292	0	0

Table A-14. Phenol data in Green/Duwamish Watershed

Phenol Summary Table																
Waterbody Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1996-1997)		(2004-2012)		(2004-2011)		(1982-2012)		(2002-2012)		(1990-2012)		(1991-2004)		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	8	94	30	167	203	662	2,018	2,619	905	1,292	330	587	299	408	0	0
Lower Green River	0	0	0	0	27	296	28	28	0	0	0	0	0	0	0	0
Middle Green River	0	0	0	0	0	0	37	37	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
All Data	8	94	30	167	230	958	2,084	2,685	905	1,292	330	587	299	408	0	0
Recent Data	No Data		(2004-2012)		(2004-2011)		(2003-2012)		(2002-2012)		(2003-2012)		(2004)		No Data	
Duwamish Estuary	0	0	30	167	203	662	782	1,046	897	1,284	204	409	283	290	0	0
Lower Green River	0	0	0	0	27	296	22	22	0	0	0	0	0	0	0	0
Middle Green River	0	0	0	0	0	0	36	36	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	0	0	30	167	230	958	840	1,104	897	1,284	204	409	283	290	0	0

Table A-15. PAHs data in Green/Duwamish Watershed

PAHs Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1996-2012)		(2004-2012)		(1996-2011)		(1980-2012)		(2002-2012)		(1990-2012)		(1991-2004)		(2011-2012)	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	11	245	32	256	360	2,105	2,217	2,974	954	1,384	331	609	305	453	3	73
Lower Green River	4	37	0	0	115	528	49	50	0	0	0	0	0	0	2	33
Middle Green River	4	30	0	0	9	66	37	37	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0

PAHs Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1996-2012)		(2004-2012)		(1996-2011)		(1980-2012)		(2002-2012)		(1990-2012)		(1991-2004)		(2011-2012)	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
All Data	19	312	32	256	484	2,699	2,304	3,062	954	1,384	331	609	305	453	5	106
Recent Data	(2007-2012)		(2004-2012)		(1996-2011)		(2003-2012)		(2002-2012)		(2003-2012)		(2003-2004)		(2011-2012)	
Duwamish Estuary	2	33	32	256	360	2,105	926	1,295	946	1,376	205	431	285	296	3	73
Lower Green River	3	35	0	0	115	528	23	23	0	0	0	0	0	0	2	33
Middle Green River	4	30	0	0	9	66	36	36	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	9	98	32	256	484	2,699	985	1,354	946	1,376	205	431	285	296	5	106

Table A-16. PCBs data in Green/Duwamish Watershed

PCBs Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(2005-2012)		(2004-2012)		(2003-2011)		(1980-2012)		(1998-2012)		(1990-2012)		(1984-2007)		(2011-2012)	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	12	43	35	174	126	477	2,806	4,180	1,228	1,925	558	1,541	452	934	3	25
Lower Green River	3	26	0	0	6	8	48	53	0	0	0	0	2	9	2	17
Middle Green River	3	28	0	0	0	0	37	37	0	0	0	0	7	30	0	0
Upper Green River	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0
All Data	18	97	35	174	132	485	2,892	4,271	1,228	1,925	558	1,541	462	974	5	42
Recent Data	(2005-2012)		(2004-2012)		(2003-2011)		(2003-2012)		(2000-2012)		(2003-2012)		(2003-2007)		(2011-2012)	
Duwamish Estuary	12	43	35	174	126	477	1,252	1,914	1,169	1,865	371	1,182	379	466	3	25
Lower Green River	3	26	0	0	6	8	24	28	0	0	0	0	2	9	2	17
Middle Green River	3	28	0	0	0	0	36	36	0	0	0	0	3	8	0	0
Upper Green	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PCBs Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(2005-2012)		(2004-2012)		(2003-2011)		(1980-2012)		(1998-2012)		(1990-2012)		(1984-2007)		(2011-2012)	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
River																
All Data	18	97	35	174	132	485	1,312	1,978	1,169	1,865	371	1,182	384	483	5	42

Table A-17. 4,4'-DDD data in Green/Duwamish Watershed

4,4'-DDD Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(2001-2007)		(2004-2011)		(2007-2010)		(1981-2012)		(2008-2011)		(1992-2012)		(1984-2006)		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	1	2	17	48	39	48	851	1,110	2	2	201	289	302	554	0	0
Lower Green River	0	0	0	0	2	18	46	47	0	0	0	0	2	9	0	0
Middle Green River	1	1	0	0	0	0	37	38	0	0	0	0	7	30	0	0
Upper Green River	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0
All Data	2	3	17	48	41	66	935	1,196	2	2	201	289	312	594	0	0
Recent Data	(2007)		(2004-2011)		(2007-2010)		(2003-2012)		(2008-2011)		(2003-2012)		(2003-2006)		No Data	
Duwamish Estuary	1	2	17	48	39	48	277	343	2	2	123	182	287	311	0	0
Lower Green River	0	0	0	0	2	18	22	22	0	0	0	0	2	9	0	0
Middle Green River	0	0	0	0	0	0	36	37	0	0	0	0	3	8	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	1	2	17	48	41	66	335	402	2	2	123	182	292	328	0	0

Table A-18. 4,4'-DDE data in Green/Duwamish Watershed

4,4'-DDE Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1996-2007)		(2004-2011)		(1996-2010)		(1981-2012)		(2008-2011)		(1992-2012)		(1984-2006)		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	2	89	17	48	41	51	863	1,124	2	2	204	292	303	557	0	0
Lower Green River	1	2	0	0	2	19	46	47	0	0	0	0	2	9	0	0
Middle Green River	2	5	0	0	0	0	37	38	0	0	0	0	7	30	0	0
Upper Green River	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0
All Data	5	96	17	48	43	70	947	1,210	2	2	204	292	313	597	0	0
Recent Data	(1996-2007)		(2004-2011)		(2007-2010)		(2003-2012)		(2008-2011)		(2003-2012)		(2003-2006)		No Data	
Duwamish Estuary	2	89	17	48	39	48	280	346	2	2	126	185	287	311	0	0
Lower Green River	0	0	0	0	2	19	22	22	0	0	0	0	2	9	0	0
Middle Green River	0	0	0	0	0	0	36	37	0	0	0	0	3	8	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	2	89	17	48	41	67	338	405	2	2	126	185	292	328	0	0

Table A-19. 4,4'-DDT data in Green/Duwamish Watershed

4,4'-DDT Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(2001-2007)		(2004-2011)		(2006-2010)		(1981-2012)		(2008-2011)		(1992-2012)		(1984-2006)		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	1	2	17	48	51	72	819	1,088	2	2	204	292	303	548	0	0
Lower Green River	0	0	0	0	2	19	46	47	0	0	0	0	2	9	0	0
Middle Green River	1	1	0	0	0	0	37	38	0	0	0	0	7	26	0	0
Upper	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0

4,4'-DDT Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(2001-2007)		(2004-2011)		(2006-2010)		(1981-2012)		(2008-2011)		(1992-2012)		(1984-2006)		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Green River																
All Data	2	3	17	48	53	91	903	1,174	2	2	204	292	313	584	0	0
Recent Data	(2007)		(2004-2011)		(2006-2010)		(2003-2012)		(2008-2011)		(2003-2012)		(2003-2006)		No Data	
Duwamish Estuary	1	2	17	48	51	72	280	346	2	2	126	185	287	311	0	0
Lower Green River	0	0	0	0	2	19	22	22	0	0	0	0	2	9	0	0
Middle Green River	0	0	0	0	0	0	36	37	0	0	0	0	3	8	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	1	2	17	48	53	91	338	405	2	2	126	185	292	328	0	0

Table A-20. alpha-BHC data in Green/Duwamish Watershed

alpha-BHC Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(2001-2007)		(2004-2011)		(2006-2010)		(1982-2012)		(2008-2011)		(1994-2006)		(1984-2006)		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	1	2	17	48	30	49	676	868	2	2	58	130	298	504	0	0
Lower Green River	0	0	0	0	2	19	45	46	0	0	0	0	2	9	0	0
Middle Green River	1	1	0	0	0	0	35	35	0	0	0	0	3	8	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	2	3	17	48	32	68	756	949	2	2	58	130	303	521	0	0
Recent Data	(2007)		(2004-2011)		(2006-2010)		(2003-2012)		(2008-2011)		(2003-2006)		(2003-2006)		No Data	
Duwamish Estuary	1	2	17	48	30	49	232	279	2	2	42	87	288	312	0	0
Lower Green River	0	0	0	0	2	19	22	22	0	0	0	0	2	9	0	0
Middle	0	0	0	0	0	0	35	35	0	0	0	0	3	8	0	0

alpha-BHC Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(2001-2007)		(2004-2011)		(2006-2010)		(1982-2012)		(2008-2011)		(1994-2006)		(1984-2006)		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Green River																
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	1	2	17	48	32	68	289	336	2	2	42	87	293	329	0	0

Table A-21. Dieldrin data in Green/Duwamish Watershed

Dieldrin Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1996-2007)		(2004-2011)		(1996-2010)		(1982-2012)		(2008-2011)		(1991-2012)		(1984-2006)		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	2	89	17	48	54	83	927	1,262	2	2	223	307	304	535	0	0
Lower Green River	1	2	0	0	2	19	46	47	0	0	0	0	2	9	0	0
Middle Green River	3	9	0	0	0	0	37	37	0	0	0	0	5	10	0	0
Upper Green River	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0
All Data	6	100	17	48	56	102	1,011	1,347	2	2	223	307	312	555	0	0
Recent Data	(1996-2007)		(2004-2011)		(1996-2010)		(2003-2012)		(2008-2011)		(2003-2012)		(2003-2006)		No Data	
Duwamish Estuary	2	89	17	48	54	83	284	350	2	2	126	180	288	312	0	0
Lower Green River	0	0	0	0	2	19	22	22	0	0	0	0	2	9	0	0
Middle Green River	1	4	0	0	0	0	36	36	0	0	0	0	3	8	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	3	93	17	48	56	102	342	408	2	2	126	180	293	329	0	0

Table A-22. Phthalates data in Green/Duwamish Watershed

Phthalates Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1996- 1997)		(2004-2012)		(2004-2011)		(1981-2012)		(2002-2012)		(1990-2012)		(1991-2006)		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	8	94	32	181	206	705	2,039	2,685	830	1,163	331	588	308	422	0	0
Lower Green River	0	0	0	0	27	295	46	47	0	0	0	0	0	0	0	0
Middle Green River	0	0	0	0	0	0	37	37	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
All Data	8	94	32	181	233	1,000	2,123	2,770	830	1,163	331	588	308	422	0	0
Recent Data	No Data		(1989-2012)		(2004-2011)		(2003-2012)		(2002-2012)		(2003-2012)		(2004-2006)		No Data	
Duwamish Estuary	0	0	32	181	206	705	782	1,078	821	1,154	204	409	292	304	0	0
Lower Green River	0	0	0	0	27	295	22	22	0	0	0	0	0	0	0	0
Middle Green River	0	0	0	0	0	0	36	36	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	0	0	32	181	233	1,000	840	1,136	821	1,154	204	409	292	304	0	0

Table A-23. Bacteria data in Green/Duwamish Watershed

Bacteria Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1970-2011)		(1989-2010)		(2005)		(2008)		No Data		No Data		No Data		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	20	603	3	19	3	6	0	0	0	0	0	0	0	0	0	0
Lower Green River	20	534	0	0	0	0	5	5	0	0	0	0	0	0	0	0
Middle Green River	45	852	1	2	0	0	0	0	0	0	0	0	0	0	0	0
Upper Green River	2	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bacteria Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1970-2011)		(1989-2010)		(2005)		(2008)		No Data		No Data		No Data		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
All Data	87	1,999	4	21	3	6	5	5	0	0	0	0	0	0	0	0
Recent Data	(1999-2011)		(2004-2012)		(2005)		(2008)		No Data		No Data		No Data		No Data	
Duwamish Estuary	13	428	3	19	3	6	0	0	0	0	0	0	0	0	0	0
Lower Green River	17	330	0	0	0	0	5	5	0	0	0	0	0	0	0	0
Middle Green River	23	527	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Green River	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	54	1,288	3	19	3	6	5	5	0	0	0	0	0	0	0	0

Table A-24. Ammonia-N data in Green/Duwamish Watershed

Ammonia-N Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1996-2008)		(2004-2009)		(1996-2008)		(1988-2012)		No Data		(2012)		No Data		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	10	489	5	27	25	196	421	521	0	0	54	54	0	0	0	0
Lower Green River	1	10	0	0	0	0	5	5	0	0	0	0	0	0	0	0
Middle Green River	0	0	0	0	0	0	21	21	0	0	0	0	0	0	0	0
Upper Green River	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	12	503	5	27	25	196	447	547	0	0	54	54	0	0	0	0
Recent Data	(2000-2008)		(2004-2009)		(2003-2008)		(2003-2012)		No Data		(2012)		No Data		No Data	
Duwamish Estuary	2	39	5	27	23	193	333	390	0	0	54	54	0	0	0	0
Lower Green River	1	10	0	0	0	0	5	5	0	0	0	0	0	0	0	0
Middle Green River	0	0	0	0	0	0	21	21	0	0	0	0	0	0	0	0

Ammonia-N Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1996-2008)		(2004-2009)		(1996-2008)		(1988-2012)		No Data		(2012)		No Data		No Data	
Upper Green River	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	4	53	5	27	23	193	359	416	0	0	54	54	0	0	0	0

Table A-25. Nitrite-Nitrate data in Green/Duwamish Watershed

Nitrite-Nitrate Summary Table																
Waterbody /Watershed	Ambient Surface Water Data		Point Source Reporting		Groundwater Quality Data		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment Data		Tissue Quality Data		Air Quality Data	
	(1973-2011)		(1989-2010)		(1996-2005)		No Data		No Data		No Data		No Data		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	20	598	9	42	20	215	0	0	0	0	0	0	0	0	0	0
Lower Green River	23	462	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Middle Green River	50	1,027	1	17	0	0	0	0	0	0	0	0	0	0	0	0
Upper Green River	2	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	105	2,482	10	59	20	215	0	0	0	0	0	0	0	0	0	0
Recent Data	(1995-2011)		(2004-2010)		(2002-2005)		No Data		No Data		No Data		No Data		No Data	
Duwamish Estuary	7	209	9	42	18	212	0	0	0	0	0	0	0	0	0	0
Lower Green River	18	321	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Middle Green River	27	530	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	57	1,314	9	42	18	212	0	0	0	0	0	0	0	0	0	0

Table A-26. Chlorophyll-*a* data in Green/Duwamish Watershed

Chlorophyll-*a* Summary Table																
Waterbody /Watershed	Ambient Surface Water Data		Point Source Reporting		Groundwater Quality Data		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment Data		Tissue Quality Data		Air Quality Data	
	(2000-2008)		No Data		No Data		No Data		No Data		No Data		No Data		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lower Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Middle Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	3	114	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Recent Data	(2006-2008)		No Data		No Data		No Data		No Data		No Data		No Data		No Data	
Duwamish Estuary	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lower Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Middle Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	2	111	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A-27. Orthophosphate data in Green/Duwamish Watershed

Orthophosphate Summary Table																
	Ambient Surface Water Data		Point Source Reporting		Groundwater Quality Data		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment Data		Tissue Quality Data		Air Quality Data	
	(1970-2011)		(1989-2010)		(1996-2008)		(2007)		No Data		No Data		No Data		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	10	302	2	13	7	8	0	0	0	0	0	0	0	0	0	0
Lower Green River	22	549	0	0	0	0	5	5	0	0	0	0	0	0	0	0
Middle Green River	52	1,120	1	17	0	0	21	21	0	0	0	0	0	0	0	0

Orthophosphate Summary Table																
	Ambient Surface Water Data		Point Source Reporting		Groundwater Quality Data		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment Data		Tissue Quality Data		Air Quality Data	
	(1970-2011)		(1989-2010)		(1996-2008)		(2007)		No Data		No Data		No Data		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Upper Green River	2	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	91	2,106	3	30	7	8	26	26	0	0	0	0	0	0	0	0
Recent Data	(1995-2011)		(2009-2010)		(2008)		(2008-2010)		No Data		No Data		No Data		No Data	
Duwamish Estuary	5	162	2	13	5	5	0	0	0	0	0	0	0	0	0	0
Lower Green River	18	337	0	0	0	0	5	5	0	0	0	0	0	0	0	0
Middle Green River	27	553	0	0	0	0	21	21	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	51	1,072	2	13	5	5	26	26	0	0	0	0	0	0	0	0

Table A-28. Organic carbon data in Green/Duwamish Watershed

Organic Carbon Summary Table																
	Ambient Surface Water Data		Point Source Reporting		Groundwater Quality Data		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment Data		Tissue Quality Data		Air Quality Data	
	(1995-2007)		No Data		(1996-2005)		(1990-2010)		No Data		No Data		No Data		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	1	42	0	0	3	9	1,972	3,190	0	0	0	0	0	0	0	0
Lower Green River	1	37	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Middle Green River	2	74	0	0	0	0	2	3	0	0	0	0	0	0	0	0
Upper Green River	2	28	0	0	0	0	1	1	0	0	0	0	0	0	0	0

Organic Carbon Summary Table																
	Ambient Surface Water Data		Point Source Reporting		Groundwater Quality Data		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment Data		Tissue Quality Data		Air Quality Data	
	(1995-2007)		No Data		(1996-2005)		(1990-2010)		No Data		No Data		No Data		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
All Data	6	181	0	0	3	9	1,976	3,195	0	0	0	0	0	0	0	0
Recent Data	(1995-2007)		No Data		(1996-2005)		(1995-2010)		No Data		No Data		No Data		No Data	
Duwamish Estuary	0	0	0	0	3	9	903	1,796	0	0	0	0	0	0	0	0
Lower Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Middle Green River	1	39	0	0	0	0	1	2	0	0	0	0	0	0	0	0
Upper Green River	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	2	43	0	0	3	9	904	1,798	0	0	0	0	0	0	0	0

Table A-29. Total organic carbon data in Green/Duwamish Watershed

Total Organic Carbon Summary Table																
	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1989-2012)		(1989-2011)		(2006-2011)		(1984-2012)		(2002-2012)		(1990-2012)		No Data		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	9	115	21	88	51	204	2,602	3,649	596	920	544	1,545	0	0	0	0
Lower Green River	19	208	0	0	0	0	47	58	0	0	0	0	0	0	0	0
Middle Green River	42	427	1	13	0	0	39	44	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	70	750	22	101	51	204	2,955	4,138	920	920	544	1,545	0	0	0	0
Recent Data	(2004-2012)		(2004-2011)		(2006-2011)		(2003-2012)		(2002-2012)		(2003-2012)		No Data		No Data	

Total Organic Carbon Summary Table																
	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1989-2012)		(1989-2011)		(2006-2011)		(1984-2012)		(2002-2012)		(1990-2012)		No Data		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	9	115	21	88	51	204	1,135	1,814	596	920	361	1,190	0	0	0	0
Lower Green River	17	199	0	0	0	0	29	39	0	0	0	0	0	0	0	0
Middle Green River	24	231	0	0	0	0	36	38	0	0	0	0	0	0	0	0
Upper Green River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	50	545	21	88	51	204	1,274	1,985	596	920	361	1,190	0	0	0	0

Table A-30. Dissolved oxygen data in Green/Duwamish Watershed

Dissolved Oxygen Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1959-2012)		No Data		(1996-2010)		(1994-2005)		No Data		No Data		No Data		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	30	1,046	0	0	29	81	10	120	0	0	0	0	0	0	0	0
Lower Green River	23	1,619	0	0	22	112	2	6	0	0	0	0	0	0	0	0
Middle Green River	59	6,066	0	0	9	39	4	6	0	0	0	0	0	0	0	0
Upper Green River	3	27	0	0	0	0	1	1	0	0	0	0	0	0	0	0
All Data	115	8,758	0	0	60	232	17	133	0	0	0	0	0	0	0	0
Recent Data	(1995-2012)		No Data		(1996-2010)		(1995-2012)		No Data		No Data		No Data		No Data	
Duwamish Estuary	13	537	0	0	29	81	2	112	13	537	0	0	29	81	2	112
Lower Green River	18	1,322	0	0	22	112	1	5	18	1,322	0	0	22	112	1	5
Middle Green River	27	4,400	0	0	9	39	0	0	27	4,400	0	0	9	39	0	0

Dissolved Oxygen Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1959-2012)		No Data		(1996-2010)		(1994-2005)		No Data		No Data		No Data		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Upper Green River	1	2	0	0	0	0	0	0	1	2	0	0	0	0	0	0
All Data	59	6,261	0	0	60	232	3	117	59	6,261	0	0	60	232	3	117

Table A-31. pH data in Green/Duwamish Watershed

pH Summary Table																
Waterbody /Watershed	Ambient Surface Water		Point Source Reporting		Groundwater Quality		Ambient Surface Sediment		Point Source Solids		Subsurface Sediment		Tissue Quality		Air Quality	
	(1959-2012)		(2008-2012)		(1996-2010)		(1992-2012)		No Data		(1995)		No Data		No Data	
	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples	Stations	Samples
Duwamish Estuary	24	1,057	27	150	42	223	194	211	0	0	1	2	0	0	0	0
Lower Green River	25	1,736	0	0	15	34	41	42	0	0	0	0	0	0	0	0
Middle Green River	65	6,203	0	0	8	22	42	50	0	0	0	0	0	0	0	0
Upper Green River	3	29	0	0	0	0	1	1	0	0	0	0	0	0	0	0
All Data	117	9,025	27	150	65	279	278	304	0	0	0	0	0	0	0	0
Recent Data	(1995-2012)		(2008-2012)		(1996-2010)		(2008-2012)		No Data		No Data		No Data		No Data	
Duwamish Estuary	9	405	27	150	34	136	1	1	0	0	0	0	0	0	0	0
Lower Green River	18	1,332	0	0	15	34	22	22	0	0	0	0	0	0	0	0
Middle Green River	27	4,534	0	0	8	22	35	35	0	0	0	0	0	0	0	0
Upper Green River	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Data	55	6,275	27	150	57	192	58	58	0	0	0	0	0	0	0	0