Data Report
For
Field Data Collection for the Development of a Stormwater Retrofit Plan for Water Resources Inventory Area (WRIA) 9

A Project Funded by the Puget Sound Watershed Management Assistance Program FY 2009

April 2012

King County

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April 2012

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ACRONYMS AND ABBREVIATIONS

Following are acronyms and abbreviations used frequently in this document:

ADAPS Automated Data Processing System (USGS)
USACOE United States Army Corps of Engineers
BMP Best Management Practice
CSO Combined Sewer Overflow
DHSVM Distributed Hydrology Soil Vegetation Model
DNRP Department of Natural Resources and Parks
DQO Data Quality Objective
Ecology Washington State Department of Ecology
EIM Environmental Information Management database (Ecology)
HSPF Hydrologic Simulation Program – Fortran
KC King County
LID Low Impact Development
MQO Method Quality Objectives
NPDES National Pollution Discharge Elimination System
QA quality assurance
QAPP Quality Assurance Project Plan
RSD relative standard deviation
SUSTAIN System for Urban Stormwater Treatment and Analysis Integration Model
USGS United States Geologic Survey
UW University of Washington
WLRD Water Land Resource Division (King County)
WRIA Water Resource Inventory Area
The following distribution list is all the individuals involved with the implementation of this project.

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<th>Phone</th>
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ABSTRACT

Stream flow, turbidity, water temperature and specific conductance data were collected in streams in WRIA 9 to provide data needed to refine calibration of watershed hydrologic and water quality models. These data were collected as part of a larger project to develop a stormwater retrofit plan for WRIA 9. This project includes stream flow and water quality measurements, watershed hydrologic model development and calibration, development of in-stream flow and water quality targets, and stormwater retrofit modeling.
1.0. INTRODUCTION

King County was awarded a Puget Sound Watershed Management Assistance Program FY 2009 grant by Region 10 of the U.S. Environmental Protection Agency (EPA) to conduct the Development of a Stormwater Retrofit Plan for Water Resources Inventory Area (WRIA) 9 and Estimation of Costs for Retrofitting all Developed Lands of Puget Sound. In the project work plan (http://your.kingcounty.gov/dnrp/library/water-and-land/watersheds/green-duwamish/stormwater-retrofit-project/stormwater-retrofit-workplan.pdf) Task 5, New Data Collection and Report, has the following milestones: collect continuous monitoring data by February, 2011; collect survey of low-flow data by September, 2011; complete data report by December, 2011.

This data report completes Task 5 and describes the results of the field data collection conducted as part of this grant-funded project. The data collection followed the procedures described in the Quality Assurance Project Plan for Field Data Collection for the Development of a Stormwater Retrofit Plan for Water Resource Inventory Area (WRIA) 9, (King County, 2009) otherwise referred to as the QAPP. Continuous flow, water quality and meteorological data from recorders and the results of measurements made during gage site visits in the project area are available at http://green.kingcounty.gov/wlr/waterres/hydrology/ as called for in the QAPP.

1.1 Project Need

The USGS and King County collectively maintain over 30 stream flow gages in WRIA 9. However, even with this extensive gage network, gage data are not available or insufficient for model calibration for some basins. To address this data gap, stream gages were deployed at priority new sites during the wet season of 2010/2011 (~Nov. 2010 – Feb. 2011). Turbidity and specific conductance meters were deployed at both the existing gage locations and the new sites occupied to fill data gaps to support model calibration. Instantaneous summer base flow measurements at the priority new gaging sites were also be made in July-October 2011.

1.2 Description of Study Area

The project area includes the Green/Duwamish watershed and portions of the Central Puget Sound watershed that comprise Water Resources Inventory Area (WRIA 9), excluding the areas upstream of the Howard Hanson Dam and the City of Seattle. Vashon-Maury Island, which is technically in WRIA 15 but is included in WRIA 9 for planning and restoration purposes, is also excluded from the study area. In total, WRIA 9 comprises 536 mi².

Along with unincorporated King County, there are 15 cities within the study area, (including the cities of Algona, Auburn, Black Diamond, Burien, Covington, Des Moines, Enumclaw, Federal Way, Kent, Maple Valley, Normandy Park, Renton, SeaTac, and Tukwila) and the Muckleshoot Indian Reservation. Lands within the City of Seattle are not included in the study area because the vast majority of Seattle’s lands within WRIA 9 are served by a combined sewer and stormwater system and CSO control programs are already underway in this area. The area of
WRIA 9 upstream of the Howard Hanson Dam is not included in the study area because it is primarily forested and maintained for the City of Tacoma’s water supply.

![Map of WRIA 9 showing the project area.](image)

### Figure 1  Map of WRIA 9 showing the project area.

#### 1.3 Description of Study Basins

**Newaukum Creek**

Newaukum Creek is primarily located in the Enumclaw area with several tributaries feeding into it including Big Spring Creek. The creek originates in the mountains east of the Enumclaw Plateau, flows for roughly 14 miles, drains an area of approximately 27.8 square miles, and enters the Middle Green River at River Mile (RM) 40.7. Land use in the Newaukum Creek basin has gone from historic forested lands to agriculture and now to rural residential. The upland part of the basin was noted to consist primarily of commercial forest production in 2000 and will likely remain in commercial forest production. The mid-section of the creek, known as the Enumclaw Plateau, consists of agriculture including grazing pasture, low- and low-to-high density residential, and commercial land uses.¹

Big Spring Creek

Big Spring Creek feeds into the mid-section of Newaukum Creek and is an important cold water source for Newaukum. The cold water of Big Spring Creek originates from springs in a forested wetland at SE 416th Street and 244th Avenue SE. From the forested wetland it flows into about 2,800 ft of roadside ditches and culverts, and then into about 2,100 ft of agricultural ditches before emptying into Newaukum Creek.

Crisp Creek

The Crisp Creek basin is located in South King County between Black Diamond and Maple Valley and drains about 3,200 acres. The creek originates from several groundwater springs and runs for three miles before entering the Green River at RM 40.1. The upper reaches of Crisp Creek consist of commercial forest production. Downstream of the commercial forest the riparian area becomes wider with mostly deciduous trees. At about RM 1.05 Crisp Creek serves as the water supply for the Keta Creek Hatchery and rearing ponds. The lower reach of the creek, below the fish hatchery, includes several farms and a few single-family homes.²

O'Grady Creek

O'Grady Creek originates from a spring on the Enumclaw Plateau and then flows through the Green River Natural Area, through ravines and meadows, before it empties into the Green River oxbow.³

Soos Creek

The Soos Creek basin is located in South King County and drains into the Green River at RM 33.7. The drainage basin covers an area of about 70 square miles and is located southeast of Renton and east of Kent. There are 25 tributaries to the Soos Creek totaling over 60 linear miles. The four main tributaries to Soos Creek are Covington Creek, Jenkins Creek, Little Soos Creek, and Soosette. Land use in the Soos Creek basin consists of rural residential, agriculture, and highly urban commercial and residential areas. The western area in particular has been subject to heavy urbanization in recent years.⁴

Olson Creek

Olson Creek is located in Auburn and drains residential land in its upper and middle reaches and the historic Mary Olson Farm in its lower reach. After passing through the Mary Olson Farm, Olson Creek underpasses Green River Road through a metal pipe culvert and then empties into the Green River.

**Mill Creek**

The Mill Creek basin is roughly 22 square miles and includes portions of Kent, Auburn, Algona, and Federal Way. The 8.35 mile-long creek originates from Lake Doloff and Lake Geneva and flows through Peasley Canyon before entering the Green River at RM 23.9. Land use in the Mill Creek watershed consists of forested and residential land in the upper basin, and residential and agricultural in the lower basin.\(^5\) Not to be confused with the other Mill Creek of King County that flows into Springbrook Creek before entering the Green River.

**Springbrook Creek**

The Springbrook Creek basin is located in and around Kent and Renton. The mainstem of the creek flows for 12 miles, with an additional 19.1 miles of tributaries. Springbrook Creek flows into what remains of the Black River and then enters the Lower Green River, via the Black River, at RM 11.0. The Springbrook Creek basin drains an area of 15,763 acres and has two distinct physical settings. The eastern half of the basin has steep rolling hills. The western half of the basin is virtually flat.\(^6\)

**Tributary 0003**

Tributary 0003 flows for about 4,000 ft in Burien before it empties into the Duwamish River. Its upper reaches flow below the surface, draining stormwater from streets and residential land. Near where it crosses S 116\(^{th}\) Street, Tributary 0003 daylights into a steep ravine until its last 450 ft where it passes through a series of culverts and concrete channels before it empties into the Duwamish.

**Joes Creek**

Joes Creek is located in Federal Way and flows directly into Puget Sound. The sources of Joes Creek include Jeane Lake and a shallow ravine at Olympic View Park. The drainage area includes mostly residential land as well as portions of a golf course. After passing by the golf course, Joes Creek flows through a steep ravine for about 5,000 ft and then passes under the Dash Point Road bridge before it empties into Puget Sound.

**Lakota Creek**

Lakota Creek is located in Federal Way and flows directly into Puget Sound. The upper reaches of Lakota Creek drain heavily residential area. Lakota Creek enters a steep ravine as it underpasses Dash Point Road and its channel is then confined as it flows beside the winding road. The lower reaches of Lakota Creek flow beside a wastewater treatment plant and then through a series of log weirs with fortified banks before it empties into Puget Sound.

**McSorley Creek**

McSorley Creek flows through portions of Kent and Des Moines before it empties into Puget Sound through Saltwater State Park. McSorley Creek’s upper reaches, divided into a north and


south fork, drain heavily residential, commercial, and industrial land. The creek’s north fork drains the decommissioned Midway Landfill, and its south fork drains a series of undeveloped wetland parcels. As the two forks meet near Saltwater State Park, they enter and flow through a steep ravine until the lower 500 ft where McSorley Creek is channelized and confined by the State Park’s parking and recreation areas.

**Massey Creek**

Massey Creek is located in Des Moines and flows directly into Puget Sound. The upper reaches of Massey Creek consist of several tributaries draining mixed residential and commercial. The lower 1,100 ft of the creek is heavily confined by a channel as it passes by the Des Moines Yacht Club before it empties into the Puget Sound.

**Des Moines Creek**

Des Moines Creek flows through portions of Des Moines and SeaTac and empties directly into Puget Sound. The upper reaches of Des Moines Creek drain heavily residential, commercial, and industrialized areas including SeaTac Airport and a large golf course. After it passes through the golf course, Des Moines Creek flows through Des Moines Creek Park where the creek has an extensive buffer area until it empties into Puget Sound.

**Miller Creek**

Miller Creek flows for roughly six miles through the urban area of Burien and along with several tributary streams drains adjacent communities including White Center, SeaTac (and a portion of the SeaTac Airport), and Normandy Park. Lora Lake, Lake Reba, and groundwater seeps also supply water to Miller Creek flow. Additionally, unnatural pumping of stormwater runoff from the Hermes Depression into Miller Creek supplies water to Miller Creek. As Miller Creek flows through the Normandy Park community, its channel is confined and its once estuarine outlet into Puget Sound is filled due to development.

### 2.0. FIELD SAMPLING ACTIVITIES

The field sampling effort was designed to collect data needed to improve the geographic scale of the hydrologic model calibration throughout the project area. Table 1 summarizes the flow and water quality data collection sites. The QAPP called for the following field data collection actions:

- Install 10 stream gages in the study area between October 2010 and March 2011. Maintain each stream gage for a minimum of 3 months.
- Deploy 6 turbidity probes and 14 turbidity + specific conductance sondes in the study area, rotating between sites in one-month intervals to collect data from 20 locations.
- Return to all stream gaging locations during August, 2011 to measure summer baseflow.

---

The QAPP was finalized December 10, 2011. Preparation for field activities started started in the early fall once the QAPP was effectively approved. The time it took for the purchase requests for the new monitoring equipment to work through the county system was a limiting factor in the timely installation of the new equipment. Eight of the new monitoring sites were installed with their sondes by early November, and the other two were installed by December 7 which was before the large rain storm of December 12. The turbidity probes were not received until December. They were all in installed by early January.

### Table 1. Overview of Gauging Sites and Equipment

<table>
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<tr>
<th>Green River Tributaries</th>
<th>Tributary</th>
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<td>New KC</td>
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<td>YSI 6600</td>
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<td>YSI 600-OMS</td>
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<td>New KC</td>
<td></td>
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<td>11D</td>
<td>Probe</td>
<td>N</td>
<td>Existing KC</td>
<td></td>
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<tr>
<td>Miller Creek</td>
<td>42A</td>
<td>Probe</td>
<td>N</td>
<td>New KC</td>
<td></td>
</tr>
</tbody>
</table>

### 2.1 Deviations from the QAPP

The level of effort for data collection activities called for in the QAPP was met or exceeded at all sites. The site 44G Newaukum tributary at 236th AV SE in the initial scope was replaced by
gage 44N on Newaukum Creek at SE 416th ST which represented a more significant area of the watershed. The QAPP called for the use of turbidity probes with data loggers at six sites. Only five probes were available from the manufacturer in time for the project. So at site 03G, a YSI 6000 sonde that was being reserved as a backup was used. The YSI 6000 was replaced by a newer YSI 600 OMS when it became available from another project. The recording stream gages added for the project were allowed to record through the end of the water year (September 30) instead of being removed at the end of March. Summer low flows were still measured in August. The only exception was site 44N which was discontinued July 15, 2011 and not measured subsequently because a bridge construction project made the site inaccessible. The five sites with turbidity probes collected turbidity data through the end of the water year.

The QAPP (Section 3.2) mentions pH as a parameter to be measured as part of the ongoing water quality monitoring at the existing stream gage sites in the project area. pH data have not been collected at these sites previously and was not measured during the project monitoring either.

### 2.2 Stream Gaging at Existing Sites

Figure 2 displays the location of the ten previously existing stream gages in the study area. The data from these gages will be used to help calibrate the watershed hydrologic models. King County maintained eight of the locations in the project area as part of its routine environmental monitoring program and special project monitoring. USGS maintains stream flow gages at two locations in the project area. Both King County and USGS measure stream flow continuously (15-minute intervals) at these sites. Six of the King County sites were telemetered as were both USGS sites. Stream discharge was measured at least six times at each gage during the project monitoring period. Data from the county stream gages was entered in the KC hydrologic database following the usual procedures.

### 2.3 Meteorological Monitoring

Precipitation was measured at the 18 locations shown in Figure 3. The site at the Summit King County Roads maintenance facility has a meteorological station which measures precipitation, air temperature, wind speed, wind direction, solar radiation, relative humidity, and calculates an evapotranspiration estimate. Ten of the rain gages were telemetered. Each monitoring site was maintained and instrument calibration checked during the monitoring period.

### 2.4 Project-Specific Stream Gaging

As part of this project, 10 stream gages were established to provide flow data (Figure 4). Where possible, the new stream gages recorded through the end of September. At least 12 direct measurements of discharge were made at each of the new gage locations during the project monitoring period. Water level data was corrected to observed water level and entered in the KC hydrologic database. A stage – discharge rating curve was developed for each site and used to calculate streamflow.
2.5 Project-Specific Water Quality Monitoring

As part of the project, continuous turbidity and specific conductance monitoring was performed at the 20 stream gages. Turbidity and specific conductance was measured with sondes at 15 locations during the October 2010 through March 2011 period. At five locations, turbidity probes were installed with the stream gage equipment to record turbidity during the monitoring period. Figure 5 shows the locations of the turbidity monitoring sites. Table 1 lists the sites with method used for measuring turbidity. A single technician was dedicated to maintenance and data acquisition for the water quality sondes. A logbook with a record of the location and calibration of the sondes was maintained. Any problems with the installation of the sondes discovered at site visits was recorded and used for data QC. Turbidity and specific conductance data from the sondes was entered in the KC hydrologic database. Turbidity data from the probes was QC’d and entered in the KC hydrologic database.

2.6 Site Specific Activities

- 03G Springbrook Creek. This existing stream gage (installed December 2001) used an Onset U20-004 water level logger to measure water level and water temperature. A YSI 6000 water quality sonde was installed on December 11, 2010 just before a large rain storm hit the area. The wiper on the sonde stopped working in early January so the frequency of site visits was increased to manually clean the probe. On February 4, 2011 a YSI 600 OMS sonde was added. 20 site visits were made during the project monitoring period: discharge was measured ten times; turbidity measured 17 times; water temperature, dissolved oxygen and conductivity measured 18 times. The sondes were removed April 8, 2011. The stream gage continues to operate.

- 09A Covington Creek. This existing stream gage (installed January 1988) used a Campbell Scientific CR800 data logger with sensors to measure water level, turbidity and water temperature. The Forest Technology Systems DTS-12 SDI turbidity sensor was installed on January 10, 2011. The gage is telemetered. 12 site visits were made during the project monitoring period: discharge was measured ten times; turbidity measured three times; water temperature, dissolved oxygen and conductivity measured 10 times. The stream gage continues to operate.

- 11D Des Moines Creek at Mouth. This existing stream gage (installed January 1988) used a Campbell Scientific CR200 data logger with sensors to measure water level, turbidity and water temperature. The Forest Technology Systems DTS-12 SDI turbidity sensor was installed on December 29, 2010. The gage is telemetered. 17 site visits were made during the project monitoring period: discharge was measured 15 times; turbidity measured three times; water temperature, dissolved oxygen and conductivity measured 11 times. A public works project by the City of Des Moines caused the stream to bypass the gage during the summer of 2011. No continuous streamflow data are available for that period (July 14 – September 14, 2011). The turbidity sensor was removed in July when the stream channel was dewatered. The stream gage continues to operate.
• 13A Duwamish River tributary 0003. This new stream gage (installed November 10, 2010) used an Onset U20-004 water level logger to measure water level. A YSI 600 OMS water quality sonde was installed on November 10, 2010. 16 site visits were made during the project monitoring period: discharge was measured 14 times; turbidity measured 11 times; water temperature, dissolved oxygen and conductivity measured 14 times. The sonde was removed April 15, 2011. The stream gage operated until October 18, 2011. A stream gage was operated by King County at the same location between 1993 and 1995.

• 26A Jenkins Creek. This existing stream gage (installed December 1987) used a Campbell Scientific CR800 data logger with sensors to measure water level, turbidity and water temperature. The Forest Technology Systems DTS-12 SDI turbidity sensor was installed on January 6, 2011. The gage is telemetered. Nine site visits were made during the project monitoring period: discharge was measured eight times; turbidity measured three times; water temperature, dissolved oxygen and conductivity measured nine times. The stream gage continues to operate.

• 32C Olsen Creek. This new stream gage (installed December 7, 2010) used an Onset U20-004 water level logger to measure water level. A YSI 600 OMS water quality sonde was installed on November 10, 2010. 14 site visits were made during the project monitoring period: discharge was measured 14 times; turbidity measured eight times; water temperature, dissolved oxygen and conductivity measured 13 times. The sonde was removed March 29, 2011. The stream gage operated until October 25, 2011. A stream gage was operated by King County at the same location between 1988 and 1990.

• 33A Joe’s Creek. This site is installed near a City of Federal Way stream gage. King County staff added new equipment for this project. This new stream gage (installed November 5, 2010) used an Onset U20-004 water level logger to measure water level. A YSI 600 OMS water quality sonde was installed on November 10, 2010. 16 site visits were made during the project monitoring period: discharge was measured 14 times; turbidity measured eight times; water temperature, dissolved oxygen and conductivity measured 14 times. The sonde was removed March 28, 2011. The stream gage operated until October 3, 2011. A stream gage was operated by USGS (12103250) at the same location between 1986 and 1988.

• 33B Lower Puget Sound tributary 0386 (Lakota Creek). Robinson Noble consultants operate a stream gage installation at this site and supplied recorded 15-minute water level data to King County for this study. County staff performed discharge measurements and developed a stage – discharge rating curve for the site. This new stream gage flow record runs October 1, 2010 through September 30, 2011. A YSI 600 OMS water quality sonde was installed on November 10, 2010. 13 site visits were made during the project monitoring period: discharge was measured 10 times; turbidity measured 11 times; water temperature, dissolved oxygen and conductivity measured 12 times. Six discharge measurement made by Robinson Noble staff were used. The sonde was removed March 28, 2011. A stream gage was operated by King County near the same location between January 20, 1989 and September 6, 1991.
- **33D McSorley Creek.** This new stream gage (installed November 5, 2010) used an Onset U20-004 water level logger to measure water level. A YSI 600 OMS water quality sonde was installed on November 8, 2010. 15 site visits were made during the project monitoring period: discharge was measured 15 times; turbidity measured nine times; water temperature, dissolved oxygen and conductivity measured 13 times. The sonde was removed April 13, 2011. The stream gage operated until October 3, 2011.

- **33E Massey Creek.** This new stream gage (installed November 5, 2010) used an Onset U20-004 water level logger to measure water level. A YSI 600 OMS water quality sonde was installed on November 8, 2010. 18 site visits were made during the project monitoring period: discharge was measured 15 times; turbidity measured 10 times; water temperature, dissolved oxygen and conductivity measured 14 times. The sonde was removed April 13, 2011. The stream gage operated until October 3, 2011.

- **40C O’Grady Creek.** This new stream gage (installed October 28, 2010) used an Onset U20-004 water level logger to measure water level. A YSI 600 OMS water quality sonde was installed on November 9, 2010. 15 site visits were made during the project monitoring period: discharge was measured 12 times; turbidity measured eight times; water temperature, dissolved oxygen and conductivity measured 13 times. The sonde was removed April 7, 2011. The stream gage operated until October 25, 2011. A stream gage was operated by King County at the same location between 1991 and 1995.

- **40D Crisp Creek.** This existing stream gage (installed August 1994) used a Campbell Scientific CR800 data logger with sensors to measure water level and water temperature. The gage is telemetered. The channel is very dynamic at this site since the property owner removed an in-stream culvert that anchored channel elevation. A YSI 6600 was installed at the site to record turbidity, temperature and conductivity. The sonde was not found at the January 31 site visit. A YSI 600 OMS was installed February 4, 2011 and removed May 12, 2011. 26 site visits were made during the project monitoring period: discharge was measured 23 times; turbidity measured three times; water temperature, dissolved oxygen and conductivity measured 17 times. The stream gage continues to operate.

- **41C Mill Creek at Peasley Canyon.** This new stream gage (installed October 28, 2010) used an Onset U20-004 water level logger to measure water level. A YSI 6600 water quality sonde was installed on November 12, 2010. 14 site visits were made during the project monitoring period: discharge was measured 13 times; turbidity measured seven times; water temperature, dissolved oxygen and conductivity measured 13 times. The sonde was removed March 28, 2011. The stream gage operated until October 25, 2011. A stream gage was operated by King County at a nearby location between 1989 and 1992 and from 2004 to 2008.

- **42A Miller Creek.** A new stream gage was established for the project upstream of a long term existing stream gage (installed January 1988) in a better location. The new site used a Campbell Scientific CR200 data logger with sensors to measure water level, turbidity
and water temperature. The Forest Technology Systems DTS-12 SDI turbidity sensor was installed on January 4, 2011. The gage is telemetered. 14 site visits were made during the project monitoring period: discharge was measured 14 times; turbidity measured three times; water temperature, dissolved oxygen and conductivity measured nine times. The new stream gage continues to operate.

- **44A Newaukum Creek.** This is a USGS stream gage operated by that agency primarily for the USACOE to inform operation of the Howard Hanson dam for flood control. The gage ran continuously throughout the project monitoring period. Streamflow data were downloaded by King County staff from the USGS ADAPS database. A YSI 6600 water quality sonde was installed on November 9, 2010. 19 site visits were made during the project monitoring period: discharge was measured six times by the USGS; turbidity measured eight times by King County staff; water temperature, dissolved oxygen and conductivity measured 13 times. The sonde was removed April 13, 2011.

- **44I Big Spring Creek.** This existing stream gage (installed April 2007) used an Onset U20-004 water level logger to measure water level and water temperature. A YSI 600 OMS water quality sonde was installed on November 15, 2010. 11 site visits were made during the project monitoring period: discharge was measured ten times; turbidity measured eight times; water temperature, dissolved oxygen and conductivity measured 10 times. The sonde was removed April 18, 2011. The stream gage continues to operate.

- **44N Newaukum Creek at SE 416th.** This new stream gage (installed October 29, 2010) used an Onset U20-004 water level logger to measure water level. A YSI 6600 water quality sonde was installed on November 9, 2010. 11 site visits were made during the project monitoring period: discharge was measured seven times; turbidity measured eight times; water temperature, dissolved oxygen and conductivity measured 10 times. The sonde was removed April 18, 2011. The stream gage operated until July 15, 2011. A King County bridge replacement project at the stream crossing at that forced removal of the gage and prevented safe measurement of streamflow.

- **54A Soos Creek.** This is a USGS stream gage that has operated at that since 1960. The gage ran continuously throughout the project monitoring period. Streamflow data were downloaded by King County staff from the USGS ADAPS database. A YSI 6600 water quality sonde was installed on November 15, 2010. 20 site visits were made during the project monitoring period: discharge was measured six times by the USGS; turbidity measured eight times by King County staff; water temperature, dissolved oxygen and conductivity measured 14 times. The sonde was removed April 7, 2011.

- **54i Little Soos Creek.** This existing stream gage (installed December 1995) used a Campbell Scientific CR800 data logger with sensors to measure water level, turbidity and water temperature. The Forest Technology Systems DTS-12 SDI turbidity sensor was installed on December 10, 2010. The gage is telemetered. 13 site visits were made during the project monitoring period: discharge was measured 10 times; turbidity measured three times; water temperature, dissolved oxygen and conductivity measured 12 times. The stream gage continues to operate.
- 54J Soos Creek at Kent-Black Diamond RD. This new stream gage (installed October 28, 2010) used an Onset U20-004 water level logger to measure water level. A YSI 6000 water quality sonde was installed on November 18, 2010. 14 site visits were made during the project monitoring period: discharge was measured 12 times; turbidity measured 10 times; water temperature, dissolved oxygen and conductivity measured 13 times. The sonde was removed April 4, 2011. The stream gage operated until October 25, 2011. The USGS operated a stream gage at the same location in 1985 through 1986.
Figure 2  Location of Existing Stream Gages
Figure 3  Location of Existing Weather Monitoring Sites
New Gauges

Figure 4 Location of New Stream Gages
Figure 5  Location of Turbidity Monitoring Sites
### Table 2. List of Stream Gage and Turbidity Monitoring Locations

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<tr>
<th>SITE_CODE</th>
<th>SITE_NAME</th>
<th>Lat</th>
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<th>NTU</th>
<th>Sp. Cond</th>
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<td>33A</td>
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<td>122.0270</td>
<td>Sonde</td>
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<td>121.9730</td>
<td>Sonde</td>
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3.0. RESULTS

Water Year 2011 was wetter than normal. Figure 6 shows the accumulated rainfall at two sites for Water Year 2011, along with an average of the last 11 years for each site. The Des Moines site represents the western part of the study area, Black Diamond the eastern part. The plentiful rainfall was good for acquiring data on stormwater conditions in the monitored streams.

Stormflow discharge measurements were made at each of the new gage sites. Some of the small streams experienced channel erosion and deposition that degraded the streamflow data quality. The positioning of the water quality sondes and probes in small streams required frequent adjustment. Nearly every site suffered some loss of water quality data due to channel changes that left the sonde or probe out of water or buried in sediment. Only data we know to be in error are not included in the database. Each site does have significant periods of useful turbidity data. Section 3.1 discusses conditions affecting data quality for each site. Section 3.2 contains charts of the continuous discharge data plotted with the recorded turbidity. Specific conductance data are plotted with water temperature where applicable. The specific conductance results are not discussed for each site. Notable was a spike in conductivity values at many sites in late February after a period of snow and freezing weather. We attribute the increase in values to road de-icing chemicals washing into the stream.

![Figure 6](image_url)

**Figure 6** 2011 Rainfall at Two Sites
3.1 Results by Site

- **03G Springbrook Creek.** The creek is transitioning into a wetland at the gage site and as a consequence is mucky and slow moving. The flow record is fair. The water level sensor displayed daily fluctuations of up to 0.3 feet during low flow periods. The sensor seems to be exaggerating the actual daily fluctuation which is more likely in the range of 0.05 feet based on previous data collected with a different sensor. The YSI 6000 water quality sonde produced a good turbidity data set for the first 20 days but then the probe wiper failed. Another 10 days of water quality data were acquired in January that appear accurate. On February 4, 2011 a YSI 600 OMS sonde was added. The probe wiper was not always up to the task of keeping a buildup of biological slime off the sensor. We removed data that was obviously in error, but some of the remaining data are questionable.

- **09A Covington Creek.** The flow record for this gage is good. Data for January 25 – January 31 was lost due to a data logger programming error. Flow data are estimated for that period. The Forest Technology Systems DTS-12 SDI turbidity sensor performed well. The turbidity data indicate that significant sediment transport may not occur in the stream until flow is in excess of 100 cfs for over 24 hours. The peak flow of 194 cfs on December 12 was the ninth highest annual peak in 24 years of record.

- **Gage 11D Des Moines Creek at Mouth.** The flow record for this gage is good. Discharge for October 1 – November 1, 2010 is estimated due to a public works project by City of Des Moines which bypassed flow around the gage installation. The Forest Technology Systems DTS-12 SDI turbidity sensor installed on December 29, 2010 worked well. The turbidity probe reading on March 9 matched a stormflow sample of 430 NTU. Considerable work, including a high flow bypass, has been done on Des Moines Creek in recent years to reduce the peak stormflows. The peak flow of 201 cfs on December 12 was the tenth highest annual peak in 20 years of record.

- **13A Duwamish River tributary 0003.** This stream is very flashy and turbulent. High flows above 10 cfs do not persist very long so a direct measurement of peak flow was not made. Instead, the high flow end of the rating was developed using the USGS Culvert Analysis Program (Fulford, 1997). The annual peak flow of 75 cfs was recorded on December 12, 2010. The YSI 600 OMS water quality sonde installed on November 10, 2010 produced a good turbidity record. There are no gaps in the record and the recorded values matched the measured stream turbidity.

- **26A Jenkins Creek.** This stream gage operated well throughout the monitoring period. Peak flow was 210 cfs on December 12, 2010. This was seventh highest annual peak in 24 years of record. The Forest Technology Systems DTS-12 SDI turbidity operated continuously. Turbidity was low during the monitoring period. The maximum reliable reading was 14 NTU in March. There are some larger spike reading of turbidity in the
record. These single record low flow readings are likely not the result of sediment transport in the stream. Some of the spike readings were removed from the record.

- 32C Olsen Creek. Flows in the Green River in excess of about 5,000 cfs as measured at the USGS Auburn gage flooded the Olsen Creek gage. As a result, discharge is not calculated for the following periods: December 12 -17; January 14-27; March 30 – April 6; May 14-18. Otherwise the flow data are fair. Olsen Creek is shallow with a shifting gravelly bed. The YSI 600 OMS sonde was frequently out of water or buried. Periods when the sonde was reading river water, or buried or out of water are removed from the record. The readings during those periods were extremely high and extremely variable from one 15 minute record to the next.

- 33A Joe’s Creek. This creek is shallow and carries a lot of sand and gravel. The streamflow data are fair. There are no periods of missing data. The YSI 600 OMS water quality sonde did not operate correctly for the period December 13 – 16, and data for that period are removed. A turbidity measurement on December 12 of 345 NTU matched the sonde reading at that time.

- 33B Lower Puget Sound tributary 0386 (Lakota Creek). Flow data are good. The annual peak discharge was 35 cfs on December 12. The annual peaks for a King County gage on Lakota Creek in 1990 and 1991 were 90 cfs. The YSI 660 water quality sonde did not function properly November 12 – December 16. The data set begins December 16 and the sonde operated well for the remainder of the monitoring period. The sonde recorded turbidity readings as high as 600 NTU.

- 33D McSorley Creek. Flow data are good during the flow monitoring period. The annual peak was 150 cfs on December 12. The YSI 600 OMS water quality sonde was found out of water a few times. Data are removed for those periods. Otherwise the sonde operated well. Turbidity readings over 1000 NTU were recorded during storms indicating a heavy sediment load. A field measurement of 230 NTU was made December 12 when flow was measured at over 100 cfs.

- 33E Massey Creek. The streamflow records are fair. The annual peak flow was 116 cfs on December 12. It was difficult to keep the YSI 600 OMS water quality sonde immersed in the shallow channel. The incidence of the sonde being stranded was so frequent in the December 15 – January 10 period we excluded those data. Otherwise the sonde operated well. A field measurement of 260 NTU was made December 12 when flow was measured at 73 cfs. A turbidity field measurement of 279 NTU was made in March. The sonde readings matched the field measured turbidity during steady flow conditions.

- 40C O’Grady Creek. The streamflow record is fair. The channel underwent some erosion and deposition during the monitoring period. The peak discharge for the year was 26 cfs. The annual peaks from a King County gage on O’Grady Creek during 1992 – 1995 ranged from 16 to 32 cfs. The YSI 600 OMS water quality sonde gave a good
record of turbidity. The period December 15 – 25 contains erratic turbidity readings that should be ignored. Spawning salmon were observed in the channel at times.

- 40D Crisp Creek. The streamflow record is fair. The peak flow for the year was 28 cfs, the seventh highest in the 15 year gage record. The channel is reforming near the gage location after some restoration work was done in 2010. The sharply cut silt banks cave in occasionally sending pulses of sediment downstream. The YSI sondes recorded high turbidity events during base flow conditions that may be the result of the bank erosion. Turbidity during storm flow was low in comparison. There are some other short term spikes in turbidity that may be the result of fish swimming by.

- 41C Mill Creek at Peasley Canyon. The streamflow record is fair. Frequent erosion and deposition in the channel complicates the stage-discharge rating. The peak flow for the year was 61 cfs. The annual peaks from a King County gage on Mill Creek during 2005 – 2008 ranged from 59 to 185 cfs. The YSI 6600 water quality sonde operated satisfactorily. The sonde did not record for the period February 11-18. A field measurement of turbidity made March 9 during a rain storm was 677 NTU. The sonde recorded 426 NTU at that time. The field staff noted a road construction project upstream that seemed to by contributing to the high turbidity.

- 42A Miller Creek. Equipment failure caused loss of streamflow data for the period November 11 to January 4 at the old site. A new site installed on January 4, 2011 provides the streamflow record from then on, and is considered good. Peak streamflow for the period was 305 cfs, calculated on March 10, 2011. That is the fourth highest annual peak in 23 years of record, and is questionable but cannot be discounted. The Forest Technology Systems DTS-12 SDI turbidity sensor worked well. The probe was found buried in sediment on February 1. After the reinstallation the turbidity record is good. Recorded turbidity peaked at 1600 NTU during the large flow event March 9.

- 44A Newaukum Creek. The USGS is classifying the streamflow record as estimated for the period 10/1/2010 – 6/10/2011. The gage ran continuously throughout the project monitoring period, but the data may not conform to the highest standard for USGS to publish. Daily streamflow data were downloaded by King County staff from the USGS online database. The YSI 6600 water quality sonde installed November 9, 2010 operated continuously until removed in April. There are numerous spikes in the turbidity record that could be due to floating objects in the stream or equipment malfunction. The turbidity seem data seem particularly poor at the end of January.

- 44I Big Spring Creek. The streamflow record is fair. The creek is slow moving in a large grassy ditch that flows through a pipe downstream of the gage. The peak flow was 14 cfs, which is the same as in 2010 and lower the annual peaks of 2008 (23 cfs) and 2009 (19 cfs). The YSI 600 OMS water quality sonde did not collect data for the periods: 12/31/2010 – 1/12/2011 and 1/21 – 1/28/2011. Turbidity readings were low during storms. Some spikes of turbidity were recorded in March and April which are more likely due to floating material than suspended sediment.
• 44N Newaukum Creek at SE 416th. The streamflow record is fair at this site. While staff were unable to measure any peak stormflows, the medium flows measured combined with a regular channel shape made the rating curve extension reasonable. The YSI 6600 water quality sonde failed a week into its first deployment so there is a data gap from November 18 through December 14. The sonde recorded numerous large somewhat isolated spikes of turbidity that are unlikely the result of actual turbidity in the stream. These have been edited out of the data for the plot below.

• 54A Soos Creek. The USGS stream gage 12112600 operated continuously during the monitoring period. Provisional daily streamflow data were downloaded from the USGS online database. The annual peak flow was about 700 cfs on December 12. This ranks 20th out of 50 years of record. The YSI 6600 sonde ran continuously from November 15 – April 7.

• 54i Little Soos Creek. This long term existing stream gage has a good streamflow record. The Forest Technology Systems DTS-12 SDI turbidity sensor was installed December 10, 2010 and worked continuously. The annual peak flow of 58 cfs occurred April 2 after 1.5 inches of rain in 15 hours. This was the seventh highest annual peak in 16 years of record. The December 12 storm peaked at 27 cfs and produced higher turbidity readings. Many individual 15 minute turbidity readings were in excess of 500 NTU, but with a large variability from reading to reading. The stream carries a large leaf load in late fall which may account for some of the high turbidity readings. The stream is very shallow at low flow which presents some problems for positioning the turbidity sensor. The site gets visitors who may poke around with the equipment at times. Unreasonable turbidity readings during dry weather have been removed for the plot below.

• 54J Soos Creek at Kent-Black Diamond RD. The streamflow record is good. The annual peak flow was 338 cfs on December 13. Discharge was measured at 330 cfs shortly after the peak water level. The turbidity sensor of the YSI 6000 water quality sonde failed to operate at times. The available data show low turbidity even during periods of high discharge. The peak turbidity for the year was 19 NTU, reached on the rising limb of the December storm. Turbidity was measured at 4 NTU at the time of the 330 cfs discharge measurement.

### 3.2 Charts of Data

Two charts for each site are presented: continuous streamflow and turbidity data are plotted together with markers for observations of those parameters, and stream temperature and specific conductance (where available) are plotted together with their observations. The plotted data represent what is stored in the DNRP hydrologic database. In some cases, data displayed in the chart is “cleaned up,” i.e., data that is probably of poor quality has been removed to make the presentation more clear.
Figure 7  03G Springbrook Creek Water Year 2011
Figure 8  09A Covington Creek Water Year 2011
Figure 9 11D Des Moines Creek Water Year 2011

11D Des Moines Creek Water Year 2011

- Discharge_cfs (Q)
- Q measured
- NTU
- NTU measured

Streamflow, cfs

Turbidity, NTU

Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Water Year 2011

Specific Conductance (K), umho

Water Temperature, deg C

Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Water Year 2011

Degree C
Degree C meas
K measured

Figure 9  11D Des Moines Creek Water Year 2011
**Figure 10** 26A Duwamish Tributary 0003 Water Year 2011
Figure 11  26A Jenking Creek Water Year 2011
Figure 12  32C Olsen Creek Water Year 2011
Figure 13  33A Joe’s Creek Water Year 2011
Figure 14  33B Lakota Creek Water Year 2011
Figure 15  33D McSorley Creek Water Year 2011
Figure 16  33E Massey Creek Water Year 2011
Figure 17  40C O’Grady Creek Water Year 2011

Water Year 2011

40C O’Grady Creek Water Year 2011

Discharge_cfs (Q)  Q measured  NTU  NTU measured

Turbidity, NTU

Streamflow, cfs

Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep

Specific Conductance, umho

Deg C  Deg C measured  Sp Cond (K)  K measured

Water Temperature, deg C

Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep

Figure 17  40C O’Grady Creek Water Year 2011
Figure 18  40D Crisp Creek Water Year 2011
Figure 19  41C Mill Creek Water Year 2011
Figure 20  42A Miller Creek Water Year 2011
Figure 21  44A Newaukum Creek Water Year 2011
Figure 22    44l Big Spring Creek Water Year 2011
Figure 23  44N Newaukum Creek Tributary Water Year 2011
Figure 24  54A Soos Creek Water Year 2011
Figure 25  54I Little Soos Creek Water Year 2011
Figure 26  54J Upper Soos Creek Water Year 2011
4.0. FIELD MEASUREMENT AND QC PROCEDURES

Field activities and observations were made on standard paper forms.

4.1 Field Water Quality Measurements

During site visits to the stream monitoring locations, measurements of specific conductance, temperature, and dissolved oxygen were taken. These field parameters were measured with a YSI Pro model 2030 multi parameter hand held instrument which exceeds the detection limits listed in the QAPP. The instruments were checked for proper operation prior to each use. Calibration followed the manufacturers procedures described in the product manual.


4.2 Continuous Stream Flow

The production of continuous stream flow records followed the SOP for continuous measurement of discharge developed by King County to meet NPDES monitoring requirements. (http://green.kingcounty.gov/wlr/waterres/hydrology/NPDES-SOP.doc). The methods closely follow guidance provided by WDOE (Butkus 2005; http://www.ecy.wa.gov/pubs/0503204.pdf ). Both these procedures follow USGS standards described in the USGS Water-Supply Paper 2175 (Rantz, 1982).

4.3 Continuous Measurement of Turbidity and Specific Conductance

The project employed YSI sondes to measure turbidity, specific conductance and temperature at 15 locations. Two were older model 6000upg sondes that use model 6126 turbidity probes (no longer available). The rest were models 6600 and model 600 OMS that use the same model 6136 sensor for turbidity. All the YSI sonde turbidity sensors were calibrated using AMCO Clear® micro polymer turbidity standards formulated specifically for the model 6136 sensor and distributed by YSI. The sondes were calibrated in the lab before deployment, and then field calibrated during the monitoring period.

Five sites used Forestry Technology Systems DTS-12 sensors connected to Campbell Scientific data loggers. These turbidity probes feature solid state microprocessors that retain the factory calibration for at least 12 months and required no field calibration. The probes were bench tested with their data logger and checked for working order with 0 and 100 NTU solutions before installation. Field measurements of turbidity were made at each site to confirm their operation.

Field measurements of turbidity were made by hand filling a sample bottle from the stream near the sonde or sensor. The sample was tested using a Hach 2100P portable turbidimeter. This instrument was calibrated using Hach standard solutions following the manufacturer’s procedures.
YSI sonde specific conductance probes were calibrated before deployment using fresh calibration solution. Sensors were recalibrated in the field after cleaning if the readings did not match hand held meter reading.

The calibration of the YSI sondes followed the procedures outlined in the YSI publication [http://www.ysi.com/media/pdfs/YSI-Calibration-Maintenance-Troubleshooting-Tips-6-Series-Sondes-2-8-10.pdf](http://www.ysi.com/media/pdfs/YSI-Calibration-Maintenance-Troubleshooting-Tips-6-Series-Sondes-2-8-10.pdf). The maintenance, calibration, and deployment information for each sonde is maintained in a binder in the project file.

### 4.4 Stream Summer Baseflow Measurements

Where feasible, recording stream gages were operated through the end of September 2011. A summer low flow measurement was made in July or August.

### 5.0. DATA MANAGEMENT PROCEDURES

The Lead Hydrologic Engineer has supervised the data acquisition and management activities. Field sheets and instrument calibration logs are maintained in paper files sorted by site and instrument.

### 6.0. DATA VALIDATION

All continuous data and field measurements are entered into King County’s Hydrologic Information Center database (HIC).

Field data, such as in situ data measurements or recorded environmental observations, have been reviewed. Continuous stream gage and water quality data have been reviewed for accuracy and correct procedures. Instrument calibration data have been reviewed for compliance with project and method QA/QC requirements.

### 7.0. ORGANIZATION AND SCHEDULE

#### 7.1 Field Collection Staff List and Roles

The field data collection effort was conducted by members of the King County Department of Natural Resources and Parks (DNRP) hydrologic monitoring team. This team included:

- David Funke–King County DNRP–Lead hydrologic gager responsible for ensuring proper field data are collected.
- Brendan Grant–King County DNRP – hydrologic monitoring team, responsible for maintaining stream gages and continuous water quality equipment.
- Dan Smith–King County DNRP – hydrologic monitoring team, responsible for maintaining stream gages and continuous water quality equipment.
- Allison Vassalo – King County DNRP – temporary on hydrologic monitoring team, responsible for maintaining continuous water quality equipment.
- Jim Simmonds, King County DNRP, serves as the overall project manager.
8.0. REFERENCES


