Quality Assurance Project Plan

Old Stillaguamish River Multi-Parameter Total Maximum Daily Load Study

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August 2006

303(d) Listings Addressed in this Study
Old Stillaguamish River Channel – Dissolved Oxygen

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Abstract

The Old Stillaguamish River Channel (OSRC) is one of two channels connecting the Stillaguamish River to Puget Sound in Western Washington State. Low, freshwater inflow during the dry season causes the channel to function like a tidal slough. Segments of the OSRC were included on the 303(d) lists. Two modifications have recently been made with the potential to affect water quality, including a reverse tide gate and upgrades to the City of Stanwood Wastewater Treatment Plant.

The primary objective of the Old Stillaguamish River Channel Total maximum Daily Load is to determine the assimilative capacity of the OSRC and recommend wasteload and load allocations to address the 2004 Water Quality Assessment 303(d) List.

Background

Introduction

The Stillaguamish River runs from the Cascade Range to Port Susan of Central Puget Sound in Western Washington State (Figure 1). At river mile 2.75 (as measured from Port Susan along the main channel), the river splits into the Old Stillaguamish River channel (OSRC) and Hat Slough (Figure 2). The OSRC was the primary channel to Port Susan until a series of floods redirected flow to Hat Slough over 70 years ago. Hat Slough provides a direct pathway to Port Susan; the OSRC meanders for eight miles until it splits into the South and West passes. The South Pass transports approximately 80 percent of the flow to and from Port Susan, and the West Pass transports the remaining flow to and from Skagit Bay.

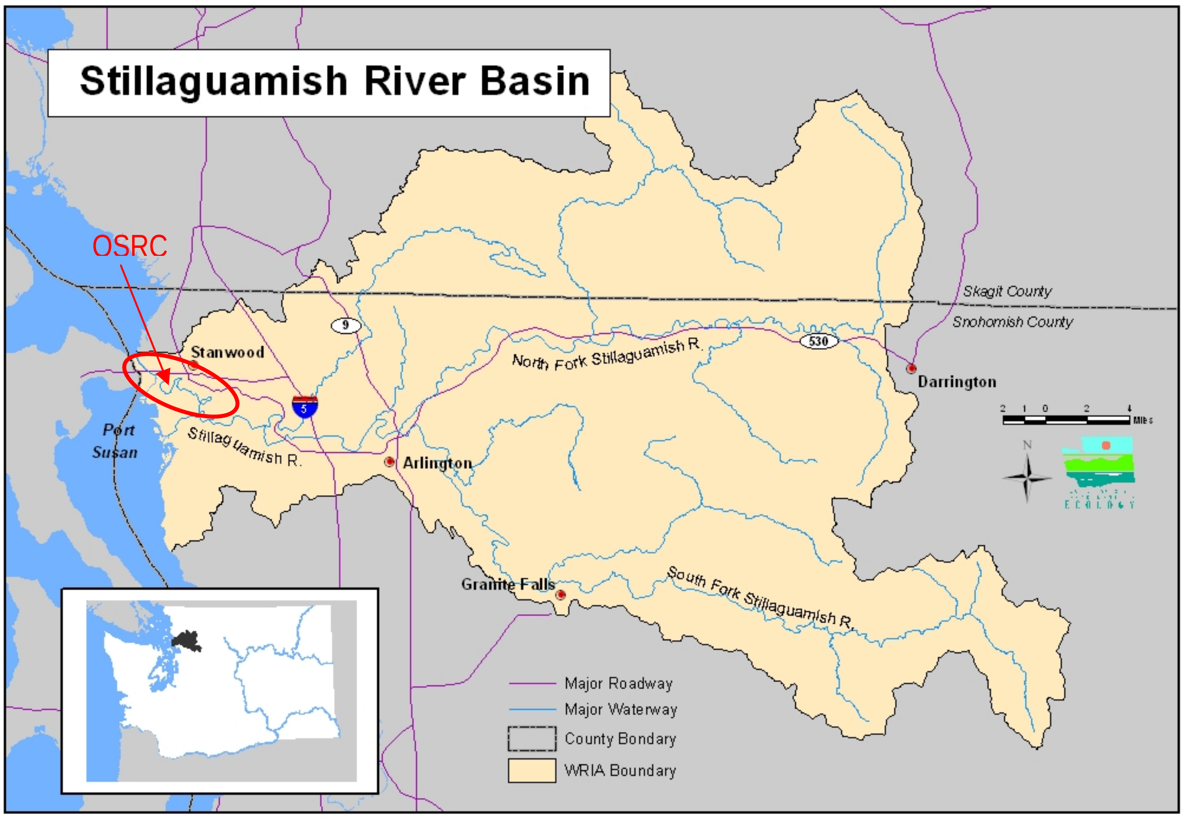

Figure 1. Overview of the Stillaguamish River basin.

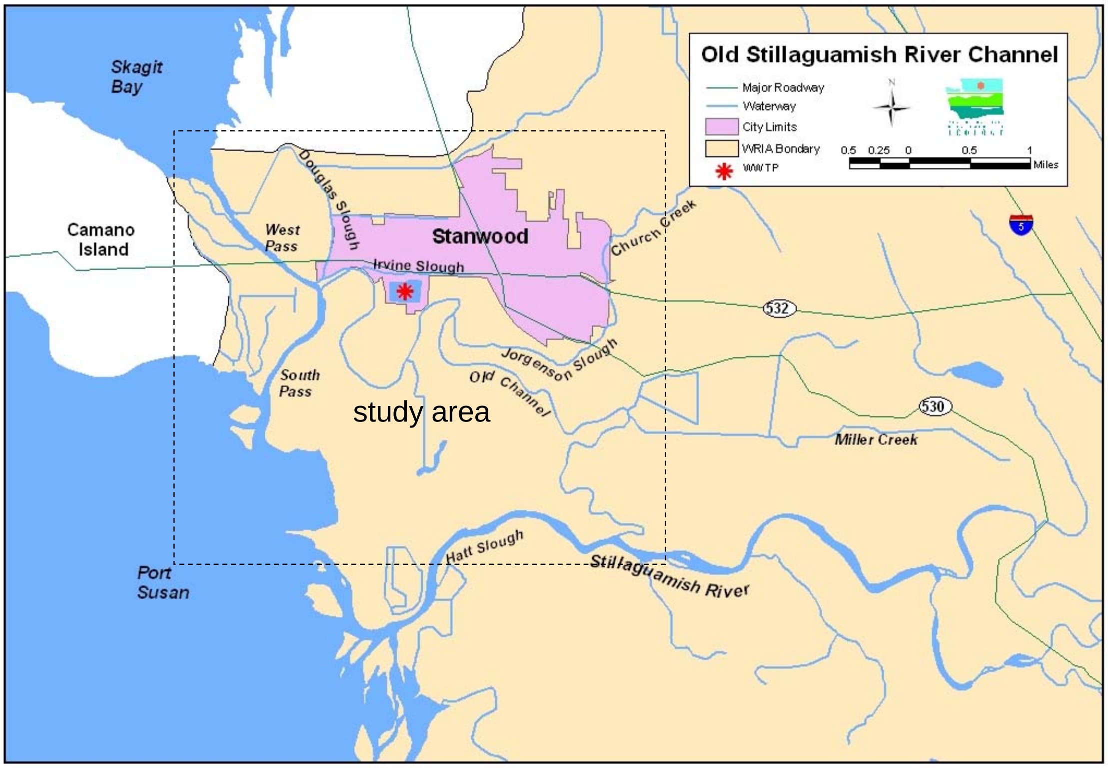

Figure 2. Overview of the Old Stillaguamish River Channel (the study area is shown in the area within the dashed lines).

The major source of freshwater to the OSRC is the Stillaguamish River. Church Creek (which drains into Jorgenson Slough), Jorgenson Slough, Miller Creek, Irvine Slough, Douglas Slough, and multiple drainage ditches also discharge into the OSRC (Figure 2). During the dry season, freshwater inflow from the Stillaguamish River, tributaries, and drainage ditches is limited and the OSRC functions much like a tidal slough. During the wet season, the OSRC is flushed by increased discharge from the Stillaguamish basin. Fewer flood events in the past couple of years have resulted in a build up of sediment and vegetation in the old channel.

Land surrounding the channel is primarily privately owned and used predominately for agricultural purposes. The City of Stanwood (population est. 3,345) is located north of the OSRC (Figure 2). The city operates a wastewater treatment plant (WWTP) that discharges into the OSRC below the confluence with Jorgenson Slough. Twin City Foods, Inc. applies food processing wastewater onto land south of the OSRC near the downstream (western) end.

In 2004, the City of Stanwood upgraded the WWTP to improve effluent quality and increase capacity. The facility has requested a National Pollutant Discharge Elimination (NPDES) permit that would authorize continuous year-round discharge.

Water Quality Issues

The OSRC and associated tributaries provide a passage for fish migration, rearing habitat, habitat for fish and wildlife, sites for secondary contact recreation, and a source of industrial and agricultural water. Federally threatened Puget Sound chinook salmon and bull trout use the OSRC as a migration route.

Calculations estimate the flushing rate of the OSRC to be three days during the dry season (Glenn, 1996). Poor flushing of contaminants may be contributing to water quality problems in the channel, especially upstream of the Stanwood WWTP outfall.

According to Chapter 173-201A of the Washington State Administrative Code (WAC), the OSRC and associated tributaries are designated as Class A waterbodies. Some areas of the OSRC qualify as Class A marine water because of salinity concentrations. Classifications are assigned based on general characteristics, characteristic uses, and water quality criteria.

Parameters of concern, listed on the final 2004 303(d) Category 5 List, for the OSRC and its tributaries include fecal coliform and temperature (Table 1). There is also one listing for dissolved oxygen in a tributary to the OSRC named Jorgenson Slough (Church Creek) based on results of a 1991 study.

Table 1. 2004 Section 303(d) Category 5 listings for the OSRC and associated tributaries.

Waterbody	Parameter	Ecology ID
JORGENSON SLOUGH (CHURCH CREEK)	Dissolved oxygen	GH05SX6.581
IRVINE SLOUGH	Fecal Coliform	HS19KT0.000
MILLER CREEK	Fecal Coliform	KX60NO0.000
SOUTH PASS SLOUGH	Fecal Coliform	UJ01AO0.000
OLD STILLY CHANNEL, WEST PASS	Fecal Coliform	XF13JD0.000
OLD STILLAGUAMISH RIVER	Temperature	QE93BW7.009

Fecal coliform listings in the OSRC were addressed in a TMDL study by Joy (2004), and temperature listings are addressed in a TMDL study by Pelletier and Bilhimer (2004). Therefore, no further TMDL studies are needed for either fecal coliform or temperature in the OSRC.

Diel surveys in the OSRC in July 2001 by Joy (2004) showed that the dissolved oxygen standard was not met in the OSRC. In July and September of 2004 diel surveys were again conducted and again the dissolved oxygen was not found to meet either the freshwater or marine water quality standards in the OSRC at any of the three stations occupied during both surveys. The TMDL study by Joy (2004) did not include evaluation of load allocations or wasteload allocations to address dissolved oxygen impairment in the OSRC.

The lack of 2004 Section 303(d) Category 5 listings for dissolved oxygen in the OSRC appears to be a result of omission of available data. Data collected by Ecology and the Stillaguamish Tribe clearly show that the OSRC exhibits dissolved oxygen below the water quality standards during two separate years of study by Ecology, and controllable human sources of nutrient loading are suspected as a contributing factor.

Tide Gate

The local Flood Control District began operating a tide gate at the head of the OSRC during the 2003 low-flow period to enhance freshwater inflow. Current management plans involve placing the gates on the concrete structure each year in July and removing the gates for the period of October through June.

Detailed information about the tide gate is available at this Web page: www.snohomishcd.org/old_stillaguamish_channel.htm.

Figure 3. The five gates in the tide gate at the head of the OSRC are in the open position in this photo, allowing inflow from the Mainstem Stillaguamish River into the OSRC. The gates close automatically to prevent flow from the OSRC into the Mainstem Stillaguamish River. The gates are removed from November through June to allow un-restricted flow.

Stillaguamish Tribe Monitoring

The Stillaguamish Tribe, in cooperation with the Stillaguamish Flood Control District, currently monitors several locations in the OSRC on a quarterly basis. The tribe records instantaneous temperature, pH, conductivity, salinity, and dissolved oxygen data and collects fecal coliform, hardness, alkalinity, turbidity, and total suspended solids grab samples.

The Nature Conservancy Port Susan Bay Restoration Project

The Nature Conservancy (TNC) currently owns approximately 4,000 acres of estuarine habitat in the Stillaguamish River delta and Port Susan Bay mudflat region. Much of the tidal wetland habitat in Port Susan Bay was diked and drained for agricultural use in the 1900s. TNC plans to restore the 160-acre property area at the mouth of the Stillaguamish River in Port Susan Bay by breaching of surrounding dikes. A three-dimensional hydrodynamic model for the Stillaguamish River and Port Susan Bay was developed by Battelle (2006) for TNC and applied to evaluate different restoration alternatives. Oceanographic data to support the modeling were collected by Evans-Hamilton (Evans-Hamilton, 2005).

Ecology Monitoring

Two surveys examining diel changes in temperature, pH, conductivity, salinity, and dissolved oxygen were conducted in the OSRC on July 28-30, 2004 and September 7-9, 2004. The purpose of the surveys was to provide new baseline data that reflects any changes a new tide gate may have on water quality in the channel. The surveys were a collaborative effort between staff of Ecology and the Stillaguamish Tribe Natural Resources Department. No comparative analysis of the 2004 data to previously collected data was provided; however, quality assurance results suggest that data collected by the Stillaguamish Tribe is comparable to Ecology data. Temperature, pH, and dissolved oxygen water quality criteria violations occurred in the OSRC during both surveys. Further monitoring was recommended.

Study Objectives

The primary objective of the OSRC TMDL study is to evaluate the assimilative capacity and recommend wasteload allocations and load allocations for pollutant sources that are contributing to dissolved oxygen problems in the OSRC. Critical conditions for dissolved oxygen in the OSRC are expected to occur in the late summer.

Project Description

A numerical model of hydrodynamics and water quality will be developed for the OSRC from the tide gate at the head of the OSRC to the downstream ends of South Pass and West Pass. The model will rely on data collected during the project by Ecology as well as existing data collected by Snohomish County, the Stillaguamish Tribe, and The Nature Conservancy. The model will be calibrated to field data. The calibrated model will then be used to evaluate the water quality in the OSRC in response to various alternative scenarios of pollutant loading. The loading capacity of the OSRC will be evaluated and wasteload allocations for point sources and load allocations for nonpoint sources will be made.

Organization and Schedule

The monitoring surveys will be conducted by the Department of Ecology during July-September 2006. The field lead for the project is Lawrence Sullivan, and Greg Pelletier is the project manager. Laboratory samples will be analyzed by Ecology's Manchester Laboratory.

Schedule

Environmental Information System (EIM) Data Set	
EIM Data Engineer	Lawrence Sullivan
EIM User Study ID	GPEL0008
EIM Study Name	OSRC TMDL
EIM Completion Due	December 2006
Final Report	
Report Author Lead	Greg Pelletier
Schedule	
Report Supervisor Draft Due	July 2007
Report Client/Peer Draft Due	August 2007
Report External Draft Due	September 2007
Report Final Due (Original)	December 2007

Data collection will occur from July through September 2006. Data collected during the OSRC TMDL study will be reviewed for quality assurance, entered into Ecology's Environmental Information Management (EIM) system, and presented in a technical memo to NWRO and the tribe. The primary objective of the diel surveys is to provide updated background data. As a result, a report analyzing the data is not scheduled.

Quality Objectives

Field measurements, methods, and associated data quality objectives are outlined in Table 2. Ecology personnel will follow Watershed Assessment Section protocols when using the multi-probe data loggers and performing Azide-modified Winkler titrations (Ecology, 1993).

Three synoptic surveys will be conducted between July and September 2006. Grab samples for conventional parameters will be collected once (tributaries) or twice (mainstem, headwater, and downstream boundary stations) per day for
2 days for each 2-day survey, directly into pre-cleaned containers supplied by Manchester Environmental Laboratory (MEL) and described in MEL (2000).

Analytical methods, sample containers, volumes, preservation and hold times are listed in Table 3. Samples for laboratory analysis will be stored on ice and delivered to MEL within 24 hours of collection.

Table 2. Field measurements, methods, and associated data quality objectives employed in the Old Stillaguamish River TMDL surveys.

Analysis	Method	Precision	Bias % Deviation from True Value	Required Reporting Limits Concentration Units
Dissolved Oxygen	Data logger/ field meter	NA	0.6 mg/L	0.1 mg/L to 15 mg/L
	Azide-modified Winkler[1]	0.2 mg/L	NA	0.1 mg/L to 15 mg/L
pH	Data logger/ field meter	0.05 s.u.	0.10 s.u.	1 to 14 s.u.
Salinity	Data logger/ field meter	<10% RSD[2]	5	0.1 ppt
Specific Conductivity	Data logger/ field meter	<10% RSD[2]	5	1 umhos/cm
Temperature	Data logger/ field meter	0.025 °C	0.05 °C	1°C to 40°C

[1] Ecology, 1993.
[2] Relative Standard Deviation.

Table 3: Summary of laboratory measurements and methods.

Parameter	Bottle	Preservative	Holding Time	EPA Method	Reporting Limit
Alkalinity	500 mL polypropylene (poly)	Cool to 4ºC	14 days	310.2	5 mg/L
Biochemical Oxygen Demand (BOD)	1 gallon cubitainer	Cool to 4ºC	48 hours	405.1	2 mg/L
Chlorophyll a	1000 mL amber	Cool to 4ºC	24 to filter 28 hrs after filter	SM 10200H(3)[1]	0.05 ug/L
Conductivity	500 mL poly	Cool to 4ºC	28 days	120.2	1 µmhos/cm
DOC	60 mL poly	HCl to pH<2, Cool to 4ºC	28 days	415.1	1.0 mg/L
Ammonia	125 mL clear poly	H_2SO_4 to pH < 2, Cool to 4ºC	28 days	SM4500[1]	0.01 mg/L
Nitrate/Nitrite	125 mL clear poly	H_2SO_4 to pH < 2, Cool to 4ºC	28 days	SM4500[1]	0.01 mg/L
Nitrogen – Total Persulfate	125 mL clear poly	H_2SO_4 to pH < 2, Cool to 4ºC	28 days	SM4500[1]	0.01 mg/L
Orthophosphate	125 mL amber poly	Cool to 4ºC	48 hours	SM4500[1]	0.003 mg/L
pH	500 mL poly	Cool to 4ºC	24 hours	150.1	
Phosphorus, Total	New 125 mL poly	HC1 to pH < 2, Cool to 4ºC	28 days	EPA 200.8	1 ug/L
Phytoplankton	500 mL amber	Lugol's solution	n/a	hand ID	n/a
Total Suspended Solids	1000 mL poly	Cool to 4ºC	7 days	160.3	1 mg/L
Total Nonvolatile Suspended Solids	1000 mL poly	Cool to 4ºC	7 days	160.4	1 mg/L
Total Dissolved Solids	500 mL poly	Cool to 4ºC	7 days	160.1	1 mg/L
TOC	60 mL poly	HCl to pH<2, Cool to 4ºC	28 days	415.1	1.0 mg/L
Turbidity	500 mL poly	Cool to 4ºC	48 hours	180.1	1 NTU

[1] SM indicates Standard Methods rather than EPA method.

Data Quality Objectives

The data quality objectives are presented in Table 4. The laboratory's measurement quality objectives and quality control procedures are documented in the MEL Lab Users Manual (MEL, 2000).

Table 4. Targets for accuracy, precision, bias, and reporting limits for the measurement systems.

Analysis	Accuracy % Deviation from True Value	Precision Relative Standard Deviation	Bias % Deviation from True Value	Required Reporting Limits Concentration Units
Field Measurements				
Velocity*	± 2% of reading +0.05 f/s 0.1 f/s	0.1 f/s	N/A	0.05 f/s
pH*	0.15 s.u.	0.05 s.u.	0.10 s.u.	N/A
Air Temperature*	± 0.4°C	0.025 °C	0.05 °C	N/A
Water Temperature*	± 0.2°C			N/A
Relative Humidity	± 3%			N/A
Dissolved Oxygen	15	< 5	5	1 mg/L
Specific Conductivity	25	<10	5	1 umhos/cm
Laboratory Analyses				
Biochemical oxygen demand	N/A	<25	N/A	2 mg/L
Dissolved Oxygen	5	<5	5	0.1 mg/L
Chlorophyll a	N/A	<20	N/A	0.05 ug/L
Total Organic Carbon	30	<10	10	1 mg/L
Dissolved Organic Carbon	30	<10	10	1 mg/L
Total Suspended/Dissolved Solids	30	<10	10	1 mg/L
Total Nonvolatile Suspended Solids	N/A	<10	N/A	1 mg/L
Alkalinity	N/A	<10	N/A	5 mgCaCO3/L
Turbidity	N/A	<10	N/A	1 NTU
Chloride	15	< 5	5	0.1 mg/L
Total Persulfate Nitrogen	30	<10	10	25 ug/L
Ammonia Nitrogen	25	<10	5	10 ug/L
Nitrate & Nitrite Nitrogen	25	<10	5	10 ug/L
Orthophosphate P	25	<10	5	10 ug/L
Total Phosphorus	25	<10	5	1 ug/L
Phytoplankton	N/A	N/A	N/A	N/A

* as units of measurement, not percentages.

Accuracy is affected by both precision and bias. The targets for analytical precision in Table 5 are based on the standard deviation of the results for check standards used to monitor measurement system performance. Targets for analytical bias are based on the difference between the mean of those results and the actual value for the check standard. Targets for accuracy are calculated at two times the target for precision plus the target for bias.

Experience at the Department of Ecology has shown that duplicate field thermometer readings consistently show a high level of precision, rarely varying by more than 0.2°C. Therefore, replicate field thermometer readings were not deemed to be necessary and will not be taken.

Sampling Process Design (Experimental Design)

Three synoptic surveys will be conducted in the OSRC during the 2006 low-flow period (July-September). The synoptic surveys will include continuous measurement of temperature, pH, dissolved oxygen, and salinity as well as grab samples for nutrients, phytoplankton, and bacteria concentrations at the network of stations shown in Figure 4. During each synoptic survey, multi-probe data loggers will be deployed at up to 7 sites (minimum of 5 sites) in the OSRC channel and possibly up to 4 sites in Jorgenson Slough (Church Creek) to log temperature, pH, dissolved oxygen, and salinity data every 15-30 minutes for 48 hours. Diel monitoring sites using Hydrolab instruments are listed in Table 5 and shown in Figure 4.

Flows from the Mainstem Stillaguamish River into the OSRC will be estimated from a flow routing model application, such as HEC-RAS (www.hec.usace.army.mil) or GEMSS (www.jeeai.com) of the Mainstem Stillaguamish and the OSRC calibrated with existing channel data collected by Snohomish County.

Table 5. Proposed monitoring sites for the OSRC TMDL surveys.

Name	Descritpion	Latitude (NAD83 harn)	Longitude (NAD83 harn)	Hydrolab	Tide gages
05TCHURH	JORGENSON SLOUGH / CHURCH CREEK	48.231184	-122.346591	x	
05TCHUR2	JORGENSON SLOUGH / CHURCH CREEK	48.231755	-122.326948	x	
05TCHUR3	JORGENSON SLOUGH / CHURCH CREEK	48.244726	-122.323893	x	
05TCHUR4	JORGENSON SLOUGH / CHURCH CREEK	48.253934	-122.298581	x	
05TDOUG	DOUGLAS SLOUGH	48.239852	-122.375867		
05TIRVIN	IRVINE SLOUGH	48.240605	-122.368864		
05TMILLR	MOUTH OF MILLER CREEK	48.221626	-122.317921		
05TMS3	MAIN STILLY CHANNEL NEAR RIVER MILE 3	48.208707	-122.322458	x	x
05TOC1	OLD STILLY CHANNEL NEAR IRVINE SLOUGH	48.239440	-122.368443	x	x
05TOC2	OLD STILLY CHANNEL NEAR STANWOOD WWTP	48.236077	-122.356352	x	x
05TOC3	OLD STILLY CHANNEL NORTH OF FLORENCE	48.225702	-122.338151	x	x
05TOC4	OLD STILLY CHANNEL AT NORMAN RD BRIDGE	48.213185	-122.326814	x	x
05TSOUTH	SOUTH PASS	48.226050	-122.385649	x	x
05TSTAN	STANWOOD WWTP	48.236183	-122.357686		
05TTCF1	TWIN CITY FOODS DRAIN 1	48.238174	-122.376111		
05TTCF2	TWIN CITY FOODS DRAIN 2	48.226129	-122.367033		
05TTCF3	TWIN CITY FOODS DRAIN 3	48.226415	-122.362672		
05TTCF5	TWIN CITY FOODS DRAIN 5	48.228872	-122.352346		
05TWEST	OLD STILLAGUAMISH CHANNEL WEST PASS	48.239948	-122.385386	x	x

Figure 4. Proposed monitoring sites for the OSRC TMDL surveys.

Continuous water level recording at the downstream boundaries in South Pass and West Pass and the upstream boundary near the tide gate from the Mainstem Stillaguamish River will be collected to determine the head boundary of the downstream and upstream ends of the model domain for the OSRC model applications. Additional continuous water level data will be collected within the OSRC between the City of Stanwood (station 05TOC1) and near the upstream end of the OSRC (station 05TOC4).

Sampling Procedures

Field sampling and measurement protocols will follow those listed in the Watershed Ecology Section (previously the Watershed Assessment Section) Protocols Manual (Ecology, 1993). Grab samples will be collected directly into pre-cleaned containers supplied by Manchester Environmental Laboratory (MEL) and described in the MEL User's Manual (2005). Sample parameters, containers, volumes, preservation requirements, and holding times are listed in Table 6. Bacteria samples for laboratory analysis will be stored on ice and delivered to MEL within 24 hours of collection via Horizon Air and an Ecology courier.

Grab samples will be collected using Watershed Ecology Section (WES) protocols (Ecology, 1993). Twenty percent of FC samples will be duplicated in the field in a side-by-side manner to assess field and lab variability. Samples will be collected in the thalweg and just under the water's surface.

Table 6. Containers, preservation requirements, and holding times for samples collected during the SFPR TMDL Study (MEL, 2005).

Parameter	Sample Matrix	Container	Preservative	Holding Time
Total Suspended Solids	Surface water, WWTP effluent, & runoff	1000 mL poly	Cool to 4ºC	7 days
Turbidity	Surface water, WWTP effluent, & runoff	500 mL poly	Cool to 4ºC	48 hours
Alkalinity	Surface water, WWTP effluent, & runoff	500 mL poly – NO Headspace	Cool to 4°C; Fill bottle *completely*; Don't agitate sample	14 days
Ammonia	Surface water, WWTP effluent, & runoff	125 mL clear poly	H_2SO_4 to pH<2; Cool to 4ºC	28 days
Dissolved Organic Carbon	Surface water, WWTP effluent, & runoff	60 mL poly with: Whatman Puradisc™ 25PP 0.45um pore size filters	Filter in field with 0.45um pore size filter; 1:1 HCl to pH<2; Cool to 4°C	28 days
Nitrate/Nitrite	Surface water, WWTP effluent, & runoff	125 mL clear poly	H_2SO_4 to pH<2; Cool to 4ºC	28 days
Total Persulfate Nitrogen	Surface water, WWTP effluent, & runoff	125 mL clear poly	H_2SO_4 to pH<2; Cool to 4ºC	28 days
Orthophosphate	Surface water, WWTP effluent, & runoff	125 mL amber poly w/ Whatman Puradisc™ 25PP 0.45um pore size filters	Filter in field with 0.45um pore size filter; Cool to 4°C	48 hours
Total Phosphorous	Surface water, WWTP effluent, & runoff	60 mL clear poly	1:1 HCl to pH<2; Cool to 4°C	28 days
Total Organic Carbon	Surface water, WWTP effluent, & runoff	60 mL clear poly	1:1 HCl to pH<2; Cool to 4°C	28 days

Measurement Procedures

Field measurements in OSRC and its tributaries will include conductivity, temperature, pH, and Dissolved Oxygen (DO) using a calibrated Hydrolab MiniSonde®. DO will also be collected and analyzed using the Winkler titration method (Ecology, 1993).

Estimation of instantaneous flow measurements will follow the Stream Hydrology Unit Protocols Manual (Ecology, 2000). Continuous stage height at selected tide gage locations will be measured by pressure transducer and recorded by a data logger every 15 minutes. All data loggers will be downloaded monthly. Staff gages may be installed at other selected sites. During the field surveys, stream flow will be measured at selected stations and/or staff gage readings will be recorded.

Quality Control Procedures

Data loggers and field meters will be calibrated according to manufacturer instructions. Calibration data will be used to evaluate field measurement accuracy. Field meters will be used to monitor data logger performance at deployment, mid-cycle (~24 hours), and pick-up. Dissolved oxygen samples for Winkler titration will be used to monitor the performance of field meter and data logger dissolved oxygen probes. Field replicates of dissolved oxygen samples will be collected at a frequency of at least 10 percent to evaluate sampling precision. Field meter data may be adjusted for bias based on Winkler titration data.

Total variation for field sampling and analytical variation will be assessed by collecting replicate samples in addition to lab duplicates and comparing those data to data quality objectives. Replicate samples will be collected at a rate of 10% of all samples. Ten percent of the filtered orthophosphate samples sent to the lab will be filter blanks to ensure filter and container quality. In addition, field blanks and total phosphorus standards will be submitted with routine samples to the laboratory to determine the presence of bias in analytical methods.

All samples will be analyzed at MEL. Costs for lab analysis include 50% discount for Manchester Lab. The laboratory's data quality objectives and quality control procedures are documented in the MEL Lab Users Manual (MEL, 2000). MEL will follow standard quality control procedures (MEL, 2000). Field sampling and measurements will follow quality control protocols described in Ecology (1993).

Results for check standards will be compared to the data quality objectives (DQO) for precision, bias, and accuracy in Table 4 wherever possible. Reporting limits for the project data will be compared to those in Table 4. If any of these targets are not met, the associated results will be qualified and used with caution.

Data Management Procedures

Field measurement data will be entered into a field book with waterproof paper in the field and then entered into EXCEL® spreadsheets (Microsoft, 2001) as soon as practical after returning from the field. This database will be used for preliminary analysis and to create a table to upload data into Ecology's EIM system.

Sample result data received from MEL by Ecology's Laboratory Information Management System (LIMS) will be exported prior to entry into EIM and added to a cumulative spreadsheet for laboratory results. This spreadsheet will be used to informally review and analyze data during the course of the project.

An EIM user study will be created for this TMDL study and all monitoring data will be available via the internet once the project data has been validated. The URL address for this geospatial database is: www.ecy.wa.gov/eim/. All data will be uploaded to EIM by the EIM data engineer once it has been reviewed for quality assurance and finalized.

All spreadsheet files, paper field notes, and GIS products created as part of the data analysis and model building will be kept with the project data files.

Audits and Reports

The project manager will be responsible for submitting quarterly reports and the final technical study report to the Water Quality Program TMDL coordinator for this project according to the project schedule. The project field lead will be responsible for completing the bacteria section of the quarterly report.

Data Verification and Validation

Laboratory-generated data reduction, review, and reporting will follow the procedures outlined in the MEL Users Manual (MEL, 2005). Lab results will be checked for missing and/or improbable data. Variability in lab duplicates will be quantified using the procedures outlined in the MEL Users Manual (MEL, 2005). Any estimated results will be qualified and their use restricted as appropriate. A standard case narrative of laboratory Quality Assurance/Quality Control results will be sent to the project manager for each set of samples.

Field notebooks will be checked for missing or improbable measurements before leaving each site. The EXCEL® Workbook file containing field data will be labeled *Draft* until data verification and validity are completed. Data entry will be checked by the field assistant against the field notebook data for errors and omissions. Missing or unusual data will be brought to the attention of the project manager for consultation. Valid data will be moved to a separate file labeled *Final*.

Data received from LIMS will be checked for omissions against the *Request for Analysis* forms by the field lead. Data can be in EXCEL® spreadsheets (Microsoft, 2001) or downloaded tables from EIM. These tables and spreadsheets will be located in a file labeled *Draft* until data validity is completed. Field replicate sample results will be compared to quality objectives in Table 12. Data requiring additional qualifiers will be reviewed by the project manager. After data validity and data entry tasks are completed, all field, laboratory, and flow data will be entered into a file labeled *Final*, and then entered into the EIM system. EIM data will be independently reviewed by another Environmental Assessment (EA) Program field assistant for errors at an initial 10% frequency. If significant entry errors are discovered, a more intensive review will be undertaken. At the end of the field collection phase of the study, the data will be complied in a data summary. Quarterly progress reports will be available every 3 months throughout the 13 month data collection period of the project.

Data Quality (Usability) Assessment

The field lead will verify that all measurement and data quality objectives have been met for each monitoring station. If the objectives have not been met, then the field lead and project manager will decide how to qualify the data and how it should be used in the analysis or whether it should be rejected.

Data Analysis and Modeling

Data reduction, review, and reporting will follow the procedures outlined in MEL's Lab Users Manual (Ecology, 2005). In addition, lab results will be checked for missing and/or improbable data. Variability of field replicates and lab duplicates will be quantified using the methods described above. Should concentrations vary over an order of magnitude during the study at any given station, standard deviation and other parameters may be analyzed using the logarithms of concentration. If lab blanks show levels of analyte above reporting limits, the resulting data will be qualified and their use restricted as appropriate.

All water quality data will be entered into Ecology's EIM system. Data will be verified and data entry will be reviewed for errors. Data analysis may include evaluation of data distribution characteristics and, if necessary, appropriate distribution of transformations. Estimation of univariate statistical parameters (e.g. minimum, maximum, mean) and graphical presentation of the data (box plots, time series, regressions) would be made using SYSTAT/SYGRAPH8 (www.systat.com) and/or EXCEL (www.microsoft.com) software.

Water quality modeling will be conducted using GEMSS (www.jeeai.com), QUAL2Kw (Pelletier and Chapra, 2003), or a similar biogeochemical modeling framework. The specific modeling framework is expected to be GEMSS, although an alternative framework may be used instead depending on a review of available frameworks at the time when modeling tasks will be conducted. The water quality model will use kinetic formulations for simulating DO and pH in the water column similar to those shown in Figure 5 and Table 7. Both GEMSS and QUAL2Kw have similar kinetic processes, and one of these, or a similar model (e.g. WASP EUTRO), will be used to analyze the fate and transport of water quality variables relating to nutrients, phytoplankton, DO, and pH interactions in the water column. The water quality model will be developed to simulate dynamic variations in water quality of the OSRC. The water quality model will be calibrated and corroborated using data collected during July through September 2006. Other data collected by Ecology and the Stillaguamish Tribe will also be used to corroborate the model to the extent possible.

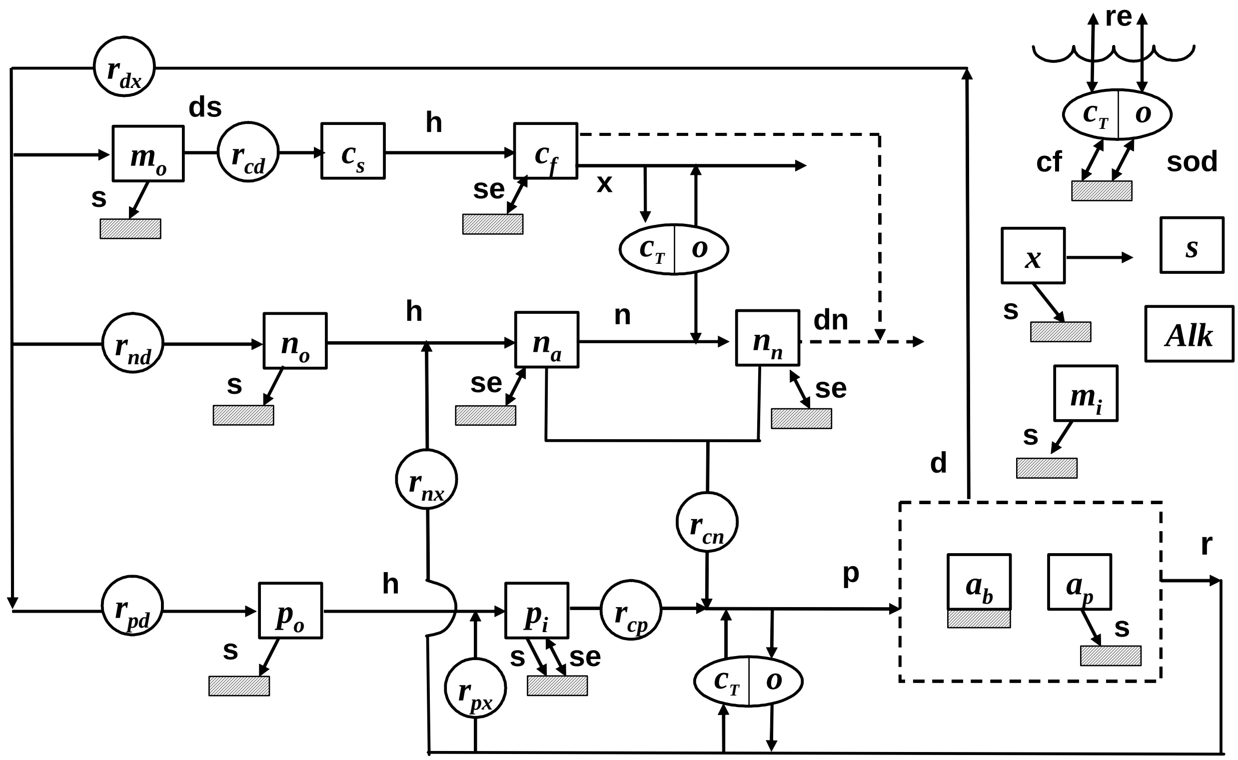

Figure 5. Model kinetics and mass transfer processes in QUAL2Kw and GEMSS.

The state variables are defined in Table 7. Kinetic processes are dissolution (ds), hydrolysis (h), oxidation (x), nitrification (n), denitrification (dn), photosynthesis (p), death (d), and respiration/excretion (r). Mass transfer processes are reaeration (re), settling (s), sediment oxygen demand (SOD), sediment exchange (se), and sediment inorganic carbon flux (cf). Note that the subscript x for the stoichiometric conversions stands for chlorophyll a (a) and dry weight (d) for phytoplankton and bottom algae, respectively. For example: r_{px} and r_{nx} are the ratio of P and N to chlorophyll a for phytoplankton, or the ratio of P and N to dry weight for bottom algae; rdx is the ratio of dry weight to chlorophyll a for phytoplankton or unity for bottom algae; r_{nd}, r_{pd}, and r_{cd} are the ratios of N, P, and C to dry weight.

Table 7. Model state variables.

Variable	Symbol	Units*	Measured as
Conductivity	s	μmhos	COND
Inorganic Suspended Solids	m_i	mgD/L	TSS-VSS
Dissolved Oxygen	o	mgO_2/L	DO
Slow-Reacting CBOD	c_s	mg O_2/L	-
Fast-Reacting CBOD	$c_{f,}$	mg O_2/L	r_{oc} * DOC or CBODU
Organic Nitrogen	n_o	μgN/L	TN – NO3N NO2N– NH4N
Ammonia Nitrogen	n_a	μgN/L	NH4N
Nitrate Nitrogen	n_n	μgN/L	NO3N+NO2N
Organic Phosphorus	p_o	μgP/L	TP - SRP
Inorganic Phosphorus	p_i	μgP/L	SRP
Phytoplankton	a_p	μgA/L	CHLA
Detritus	m_o	mgD/L	r_{dc} (TOC – DOC)
Alkalinity	Alk	$mgCaCO_3/L$	ALK
Total Inorganic Carbon	c_T	mole/L	Calculation from pH and alkalinity
Bottom Algae Biomass	a_b	gD/m^2	Periphyton biomass dry weight
Bottom Algae Nitrogen	IN_b	mgN/m^2	Periphyton biomass N
Bottom Algae Phosphorus	IP_b	mgP/m^2	Periphyton biomass P

* mg/L ≡ $g/m^{3.}$
D=dry weight.
A=chlorophyll a.
roc = stoichiometric ratio of oxygen for hypothetical complete carbon oxidation (2.69).

The following are measurements that are needed for comparison with model output:

TEMP = temperature (^oC)
TKN = total kjeldahl nitrogen (μgN/L) or TN = total nitrogen (μgN/L)
NH4N = ammonium nitrogen (μgN/L)
NO2N = nitrite nitrogen (μgN/L)
NO3N = nitrate nitrogen (μgN/L)
CHLA = chlorophyll *a* (μgA/L)
TP = total phosphorus (μgP/L)
SRP = soluble reactive phosphorus (μgP/L)
TSS = total suspended solids (mgD/L)
VSS = volatile suspended solids (mgD/L)
TOC = total organic carbon (mgC/L)
DOC = dissolved organic carbon (mgC/L)
DO = dissolved oxygen (mgO_2/L)
PH = pH
ALK = alkalinity ($mgCaCO_3/L$)
COND = specific conductance (μmhos/cm)

The model state variables can then be related to these measurements as follows:

s = COND

m_i = TSS – VSS or TSS – r_{dc} (TOC – DOC)

o = DO

n_o = TKN – NH4 – r_{na} CHLA   or n_o = TN – NO2 – NO3 – NH4 – r_{na} CHLA

n_a = NH4

n_n = NO2 + NO3

p_o = TP – SRP – r_{pa} CHLA

p_i = SRP

a_p = CHLA

m_o = VSS – r_{da} CHLA or r_{dc} (TOC – DOC) – r_{da} CHLA

pH = PH

Alk = ALK

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