2021 SAMPLING AND ANALYSIS PLAN

TAYLOR CREEK
FLOW AND SEDIMENT MONITORING PROJECT

Prepared for
Seattle Public Utilities

Prepared by
Herrera Environmental Consultants, Inc.

Note:
Some pages in this document have been purposely skipped or blank pages inserted so that this document will print correctly when duplexed.

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FLOW AND SEDIMENT MONITORING PROJECT

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INTRODUCTION

The City of Seattle (City) is implementing monitoring to characterize flow and sediment dynamics in Taylor Creek as part of the Taylor Creek Restoration Project. The project addresses localized flooding, sediment deposition, fish passage barriers, aging culverts, sewer and stormwater overflows, and the need for salmon habitat improvements throughout the watershed. Lower Taylor Creek is considered critical habitat for two focal salmon species, Puget Sound Chinook (threatened under the Endangered Species Act) and Lake Washington Watershed sockeye. Along with improving multiple ecosystem services, the restoration project will increase publicly accessible open park space in southeast Seattle. The information from this study will be used to provide an estimate of sediment flux from the basin over time, provide the information for effective adaptive management, and provide data to help assess the efficacy of channel and watershed restoration techniques (e.g., floodplain reconnection, placement of large woody debris, channel re-meandering and grade control, updated culvert placement, and riparian native plantings) on sediment flux through the watershed.

In 2019 an initial Sampling and Analysis Plan (SAP) was produced (Herrera 2019) to describe the procedures for monitoring including those used for data collection, processing, and analysis. Monitoring commenced in October 2018 and over the first 2 years it became apparent that stations should be added and methods adjusted to generate a more useful dataset. This document is a revision of the 2019 SAP and serves as the guide for monitoring which will occur in 2021. The SAP will be updated in subsequent years if methods need to adaptively change given project needs. The goal of this SAP is to ensure all results obtained from the monitoring are scientifically and legally defensible. It is organized to include the following information under separate subsections:

- **Experimental Design:** Project goals and objectives, and the information required to meet the objectives
- **Organization and Schedule:** Project roles and responsibilities, and the schedule for completing the work
- **Quality Objectives:** Performance (or acceptance) thresholds for collected data
- **Monitoring Procedures:** The procedures that will be used for the monitoring including sample types, monitoring locations, sampling frequency, and sampling procedures
- **Measurement Procedures:** Laboratory procedures that will be performed on collected samples

- **Quality Control:** Quality control (QC) requirements for both laboratory and field measurements
- **Data Management Procedures:** How data will be managed from field or laboratory recording to final use and archiving
- **Audits and Reports:** The process that will be followed to ensure this SAP is being implemented correctly and the quality of the data is acceptable
- **Data Verification and Validation:** The data evaluation process, including the steps required for verification, validation, and data quality assessment
- **Data Quality (Usability) Assessment** – The procedures that will be used to determine if collected data are of the right type, quality, and quantity to meet project objectives

EXPERIMENTAL DESIGN

Taylor Creek drains a 640-acre watershed located near the south end of Lake Washington in southeast Seattle (Figure 1). The creek originates in unincorporated King County and passes through a natural area known as Dead Horse Canyon within Lakeridge Park. It then passes through residential yards and a culvert under Rainer Avenue South before discharging into Lake Washington. To improve stream channel habitat and address storm-related flooding, the City is designing a sediment control facility upstream of the creek's crossing on Rainier Avenue South. Subsequently, the City redesigned the project to create a transitional floodplain for sediment retention and upstream engineered log jams (ELJs) to retain sediment upstream of the transitional floodplain.

To inform the design and adaptive management, and eventually quantify project performance and efficacy, the City is implementing monitoring to develop a baseline understanding of sediment transport, deposition, and sources in Taylor Creek and its tributaries. Data collected as part of this monitoring project will provide City staff with critical information for operations and maintenance of features and structures throughout the watershed, such as the new transitional floodplain as well as engineered logjams (ELJs). In addition, results from this study will inform additional watershed restoration methods, such as the placement of further ELJs, surface flow drainage improvements, and/or the acquisition of floodplain property for sediment capture and further watershed process restoration in Taylor Creek.

Given these project goals, the following objectives have been defined for the monitoring:

- Understand the pre-project and post-project flow and sediment dynamics for the Taylor Creek Watershed Restoration Project to assist in design, project performance monitoring, and adaptive management.

- Characterize flow and sediment load in the main stem of Taylor Creek and in its west and east forks.

- Construct sediment rating curves correlating suspended sediment transport and turbidity to identify locations where suspended load originates and temporarily deposits.

- Develop a mass balance model for the watershed for sediment moving through the watershed (total, suspended, bed load, and associated particle sizes) and the spatial and temporal components of how and where sediment is transported and deposited through the watershed.

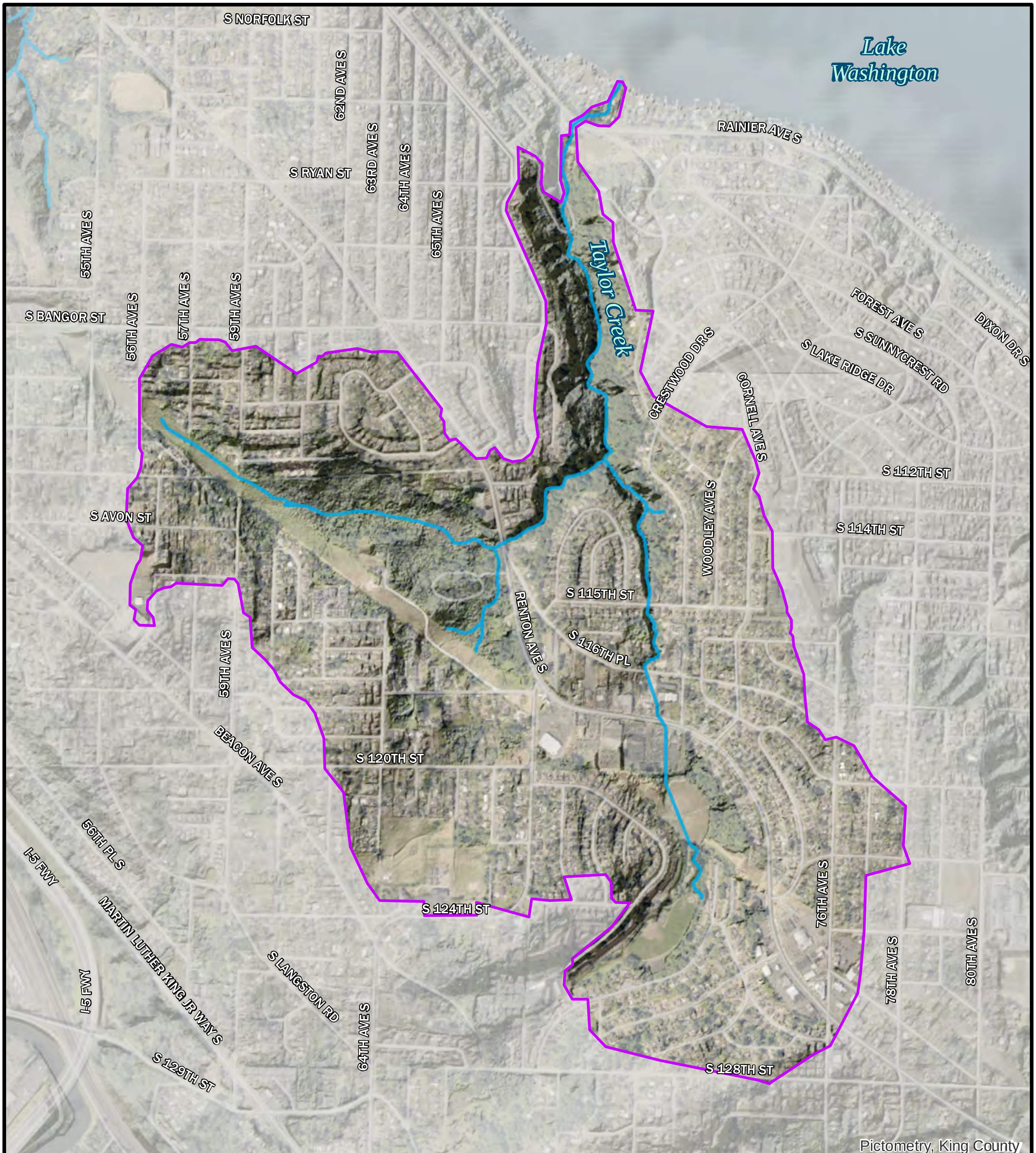
- Understand the effectiveness of large wood placement in the upper watershed for sediment attenuation and deposition through the watershed.

- Aid in the assessment of the effectiveness of floodplain reconnection for sediment attenuation.
- Assess pre- and post-watershed restoration project sediment loads and fractions in comparison with state and WRIA 8 sediment load and grain size standards in connection with water quality and salmon habitat targets.

Additional project objectives to be addressed with post-project monitoring include:

- Estimating the volumes of sediment stored by specified large wood structures.
- Comparing streambed surface sediment grain size distributions over time in the TC-Mouth reach.

To meet these objectives, the 2021 experimental design for this project will involve continuous flow monitoring at four stations (continuous monitoring stations); two on the main stem and one on each fork. Water quality sample collection (five events) and measurements of stream discharge (10 events) will also be performed at these stations. The water quality samples will be analyzed for suspended sediment concentration (SSC) for use in estimating sediment fluxes in the creek across different sized storms. A sensor will also be installed at each of these monitoring stations to collect continuous turbidity measurements. The bedload at each station will also be quantified during 10 events. A fifth monitoring station (event monitoring station) will be located near the mouth of the watershed. At this station bedload will be assessed (with occasional grab samples for SSC and turbidity). The monitoring at all five stations will continue until the target number of storm events has been sampled for each year of the project. The maximum extent of sampling would be up to 3 years post-placement of large wood structures in the upper watershed, and/or 3 years post-construction of the Lower Taylor Creek Sediment Facility and Culvert Replacement project below SPU_STA401 (Figure 2).



Legend

Watershed boundary

Stream

Street

Figure 1.
Catchment Area for Taylor Creek in Seattle, Washington.

N

0 600 1,200 2,400 Feet

HERRERA

King County, Aerial (2017)

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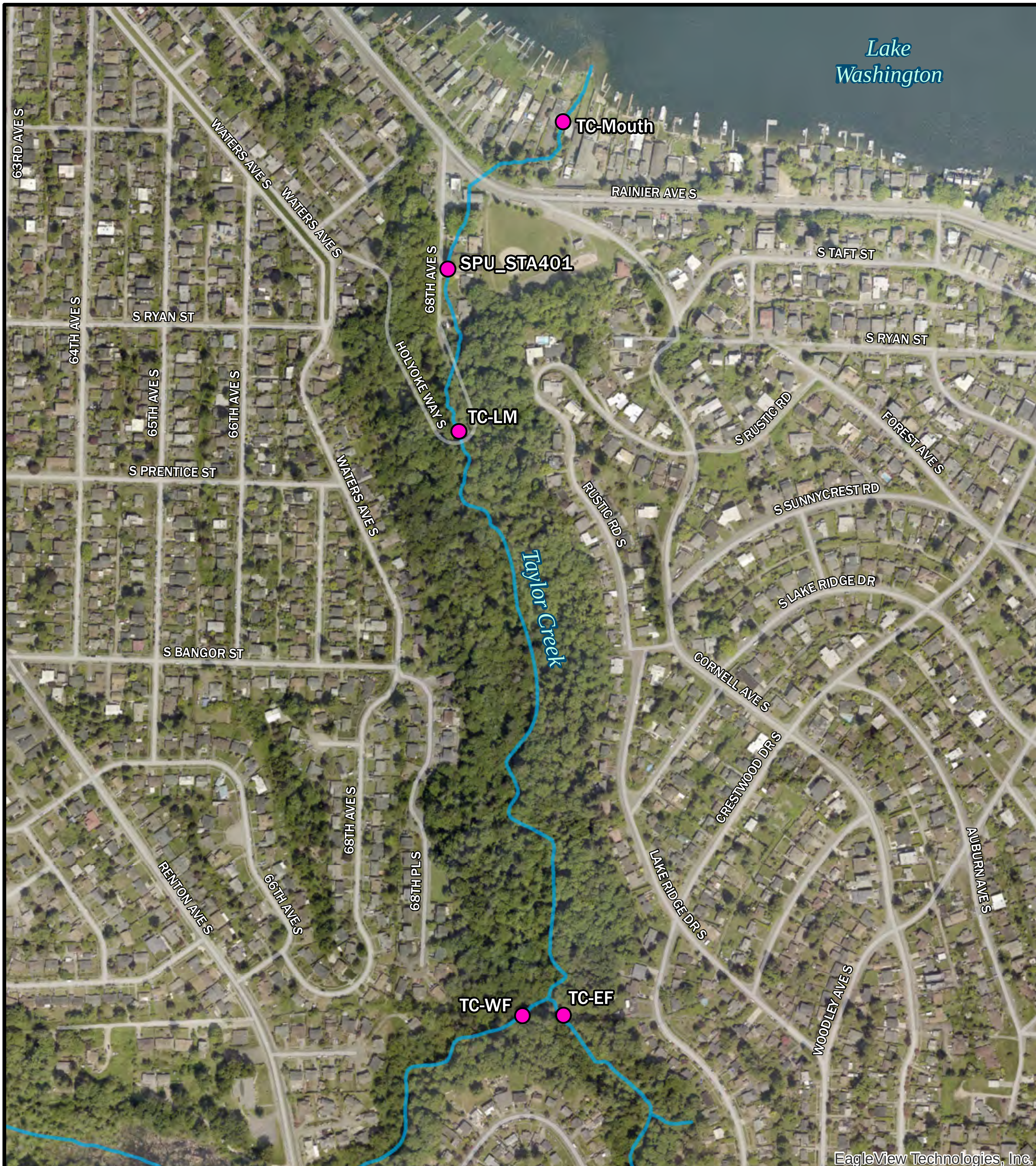

Legend

- Sampling site location
- Stream
- Street

Figure 2.
Monitoring Locations for Taylor Creek in Lakeridge Park.

0 250 500 1,000
Feet

HERRERA

King County, Aerial (2019)

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PROJECT ORGANIZATION AND SCHEDULE

This section describes how the project is organized, key personnel, and the project schedule.

ORGANIZATION AND KEY PERSONNEL

Herrera Environmental Consultants, Inc. (Herrera) is responsible for developing and implementing this SAP with oversight from the City. Required laboratory services for this project will be provided by Analytical Resources, Inc. Key personnel that will be involved in this effort are identified below with their respective roles:

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SCHEDULE

The monitoring began in October 2018, and will continue for at least 3 years post construction at all of the currently established monitoring sites with the exception of moving the array for the west fork station to the mouth station after implementation. Reporting for the project will be organized to evaluate and present the results of data collected during the effectiveness monitoring.

The project runs on a water year reporting cycle with annual reports due at the end of the calendar year each year to summarize the previous water year's data.

MONITORING PROCEDURES

This section describes the experimental design that will be used for the monitoring including field safety procedures, locations, equipment, and data collection procedures.

Field Safety Procedures

Field personnel will possess the following equipment while performing field work related to this project.

- Protective footwear
- Safety vest
- COVID-19 safety protocols as appropriate

At a minimum, field personnel will follow the general requirements for personal protective equipment (PPE) by dressing appropriately for proximity to vehicular traffic (WAC 296-155-200).

Monitoring Locations

Monitoring will occur at five locations within the watershed. One station, near the mouth of the watershed, will be used primarily for bedload assessment with no deployed sensors (Event Monitoring Station), the four other upstream stations (Continuous Monitoring Stations) will be used to assess both bedload and suspended load. The stations are named as follows and their locations are shown in Figure 2.

Event Monitoring Stations:

- Main stem station between Rainier Avenue and Lake Washington: **TC-Mouth**

Continuous Monitoring Stations:

- Main stem station upstream of Rainier Avenue South: **SPU_STA401**
- Main stem station immediately downstream of Holyoke Way South: **TC-LM**
- Upstream station in the west fork: **TC-WF**
- Upstream station in the east fork: **TC-EF**

MONITORING EQUIPMENT

Each continuous monitoring station will be equipped with a staff gauge and a water level sensor mounted within a stilling well. The water level sensor will be programmed to continuously record water level (stage) with a 5-minute logging interval for the duration of the monitoring. Station SPU_STA401 will utilize an existing Campbell CS450L water level sensor interfaced with a CR1000 datalogger that was installed by the City (Figure 3). Stations TC-WF (Figure 4), TC-EF (Figure 5), and TC-LM (Figure 6) will be equipped with RuggedTroll 100 (In Situ, Inc.) non-vented water level sensors and an *in situ* BaroTroll 100 sensor for barometric correction.

To manually collect discharge measurements a handheld Hach FH950 electromagnetic flow meter will be used. If this instrument is not available (due to conflicts with other field crews), a March McBirney Flo-Mate electromagnetic flow meter will be used instead. Data collected with these instruments will be used to determine instantaneous estimates of stream discharge which will be combined with the level data from the In Situ RuggedTroll 100 sensors to develop rating curves.

Each continuous monitoring station will be equipped with an Isco 6700 compact automated sampler to facilitate collection of composite water samples that will be analyzed for SSC. Intake strainers for the samplers will be positioned 2 inches above the bed of the creek near the thalweg to ensure they will continuously be submerged but not collect bedload.

A YSI 600 OMS Sonde with 6136 Turbidity Sensor will be installed at each continuous monitoring station in a vented stilling well (see Figure 4, left well) and programmed to continuously record turbidity with a 15-minute logging interval. The YSI sonde will not be programmed for a 5-minute data collection interval (as with the level sensors), because it would require weekly battery changes, which are not practical given the scope of this project.

At all the stations (continuous and event monitoring stations), estimates of bedload flux will be determined with the multiple equal-width-increment (MEWI) bedload-sampling method (Edwards and Glysson 1970), using a BLH-84 sampler. Bed material grain size will also be assessed on an annual basis by sampling the bed material behind a custom-built coffer dam at each station.

Finally, on an annual basis field crews will survey cross-sections at all monitoring locations using a laser level. The surveys will be tied into nearby benchmarks to convert the cross-section elevations to the same datum used for the existing survey for the whole project reach. Erosion pins placed in the channel at each station will also be surveyed.

Figure 3. SPU_STA401 Monitoring Station Showing Stilling Well and Data Logger.

Figure 4. TC-WF Monitoring Station Showing Location of Water Level Sensor Stilling Well and Turbidimeter Stilling Well.

Figure 5. TC-EF Monitoring Station Showing Location of Water Level Sensor Stilling Well and Turbidimeter Stilling Well.

Figure 6. TC-LM Monitoring Station Showing Location of Water Level Sensor Stilling Well.

FIELD DATA COLLECTION PROCEDURES

Field data collection procedures are described herein for water quality sampling, discharge and water level measurements, and bed load monitoring. Table 1 provides a chart which indicates which type of data are being collected at which station.

Table 1. Type of Data and Number of Annually Targeted Events at each Taylor Creek Monitoring Station.									
Station	Level Sensors	Flow Rate	Turbidi-meter	Auto-Samplers	Grab Samples	Bed Load	Bed Material	Cross-Section Survey	Erosion Pins
TC-EF	Cont.	10	Cont.	5	Var.	10	1	1	1
TC-WF	Cont.	10	Cont.	5	Var.	10	1	1	1
TC-LM	Cont.	10	Cont.	5	Var.	10	1	1	1
SPU_STA-401	Cont.	10	Cont.	5	Var.	10	1	1	1
TC-Mouth	–	10	Var.	–	Var.	10	1	1	1

Var. = Number of opportunistic grab samples collected per year will vary.

Cont. = Continuously collected data.

Water Quality Sampling

Twenty-four time-paced water quality samples will be collected during discrete storm events at the four continuous monitoring stations using automated sampling equipment. Antecedent conditions and storm predictions will be monitored via the Internet, and a determination will be made as to whether to target an approaching storm. Only events forecast as larger than 0.35 inch of rain will be targeted. This rainfall depth threshold is based on an assessment of flow response to rainfall depth at SPU Sta401. The objective is to target events large enough for a wide range of sediment classes to be transported, so targeting low-transport events would not meet project objectives. At SPU Sta401 the average peak flow for a 0.35 inch event is 8 CFS, whereas the maximum measured flow is 60 CFS.

Before each targeted storm event, field staff will conduct site visits to set up the automated samplers at the continuous monitoring stations. During these pre-storm site visits, field staff will perform the following activities.

- Check the state of the desiccant associated with the equipment
- Set the sample pacing and start time for each sampler
- Place clean sample bottles in the samplers
- Operate the pump to ensure there are no line clogs
- Pack ice around the sample bottles within each sampler

(Ice is estimated to keep the interior of the samplers cool for 48 hours; therefore, ice will be added to the samplers not more than 24 hours before a targeted storm event.)

Weather forecast information from the KING 5 weather website (<http://www.king5.com/weather/>) and precipitation amount predictions from the Institute of Global Environment and Society, Center for Ocean-Land-Atmosphere Studies (<http://wxmaps.org/pix/meteograms.html>) will be reviewed on a weekly basis to determine if a predicted storm event will be likely to meet the storm event criterion. To evaluate precipitation conditions immediately prior to sampling, the KING 5 weather website (<http://www.king5.com/weather/>) will be used to observe the Doppler radar display. To document precipitation conditions upon completion of the project, 5-minute precipitation data will be compiled from a nearby rain gauge (RG-30) located on the roof of the Rainier Beach Library, 1.4 miles to the northwest.

The automated samplers will be programmed to collect 24 samples over the course of the storm. If sampling criteria are not met, the samples will be disposed of before the next storm event. If sampling criteria are met, field personnel will return to the site and make visual and operational checks of the automated samplers and collect detailed field notes using standardized field forms (see *Field Quality Control Procedures*). Field personnel will then remove the 24-bottle rack from each automated sampler and select five representative sample bottles based on visual inspection of turbidity, including the bottle with the highest turbidity. The goal is to obtain a sample set that represents the entire range of storm suspended solids concentrations with as few samples as possible. On one occasion field personnel will verify their visually selected samples by having the lab assess the turbidity of all the samples in one of the sampler racks.

The selected samples will be transported on ice to the laboratory within the allowable limits for sample holding times (see Table 2). Additional samples will also be collected through the course of the monitoring for quality assurance purposes (see *Field Quality Control Procedures* section below).

These samples will be analyzed for SSC by AmTest, Inc., in Burlington, Washington. The laboratory will be given prior notice of a pending sampling event and samples will be dropped at a secure drop box located in Burlington, Washington. AmTest personnel will pick up the samples from the drop box within 12 hours.

In addition to automated samples, grab samples for SSC will be collected when discharge or bedload estimates are being made during the event. This is to ensure the collection of a wide range of samples across all flow conditions. On five occasions grab samples will be collected while composite samples are being collected. During these site visits a grab sample will be collected from the thalweg and a second from the bank within 2 minutes of the sampler firing. The three samples will be compared to determine how much variation in SSC occurs across the cross-section of the channel, and as a check of method efficacy.

Discharge and Water Level Measurements

Stream discharge will be measured at all gauging stations using a handheld velocity meter and the mid-section velocity method. Detailed procedures are included in the Standard Operating Procedures – Instantaneous Discharge Measurement in Streams and Pipes presented in Appendix A. These procedures are based on methods established by the US EPA for the Puget

Sound Estuary Program (PSEP 1996) and the United States Geological Survey (USGS 1969). A total of 10 discharge events will be targeted for stream discharge measurements.

Once in the field rebar will be driven into the bank on either side of the creek to mark a cross-sectional area for making manual measurements of discharge. The rebar will be used to anchor a graduated tape that is stretched across the creek during these measurements. In lieu of this approach an extendable stadia rod will be placed across the channel and used to marks cross-section increments. Velocity and depth measurements will then be taken in equal increments across the width of the channel.

Practical constraints may be encountered during both base flow and storm flow conditions. Accurate measurement of discharge during base flow conditions may be problematic due to the minimum depth needed for the velocity sensor to operate. It is also possible that stream flow during some storm flow conditions could be too high to allow for safe measurement of discharge.

Data from the water level sensors at stations TC-E1, TC-W1, and TC-LM will be downloaded at least monthly and stored in an Aquarius™ continuous data management database. During these visits, photos of channel conditions both upstream and downstream of the water level stilling wells will be taken to document channel conditions. Photos will also be taken during extreme high-flow events when crews are on site to collect discharge measurements.

Data from the water level sensor at station SPU_STA401 will be remotely downloaded via a Raven XTV cellular modem on a daily basis. These data will also be stored in the Aquarius™ continuous data management database.

Bedload and Bed Material Monitoring

During 10 events annually at each station field staff will employ the Multiple Equal-Width-Increment Method (MEWI) to estimate bedload (Edwards and Glysson 1970). This method consists of collecting four samples evenly spaced across the width of the channel. A BLH-84 sampler will be held for 30 seconds at each position. Once the cross-section is complete, the sampler is returned to the first of the four positions and the process is repeated, for a total of 10 cross-sections. The collected material is emptied into a composite bucket and organic debris is removed. The composite bucket is then labeled for delivery to AmTest, Inc., for weighing and grain size analysis (Table 3). The full MEWI method can be found in the Appendix A SOPs.

Once annually during summer low-flow conditions, field staff will visit all stations to collect a bed material sample following the method outlined in McNamara and Sullivan (2007). A coffer dam will be set up in the thalweg to divert flows, and field staff will collect a surface and subsurface sample behind the dam following the bed material sampling method provided in Appendix A. The samples will then be submitted to AmTest, Inc., for weighing and grain size analysis (Table 3).

Table 2. Water Quality Analysis Methods and Detection Limits.									
Parameter	**Analytical Method**	**Method Number[a]**	**Field Sample Container**	**Total Holding Time[b]**	**Field Preservation**	**Laboratory Preservation**	**Actual Reporting Limit/ Resolution**	**Target Reporting Limit/ Resolution**	**Units**
Suspended sediment concentration	Gravimetric	ASTM D3977-97B	0.5-liter HDPE bottle	7 days	Maintain ≤6°C	Maintain ≤6°C	1.0	1.0	mg/L

[a] ASTM (2003).

[b] Holding time specified in US EPA guidance (US EPA 1983, 1984) or referenced in APHA et al. (1992) for equivalent method.

°C = degrees Celsius

HDPE = high-density polyethylene

mg/L = milligrams per liter

Table 3. Sediment Quality Analysis Methods and Detection Limits.									
Parameter	**Analytical Method**	**Method Number[a]**	**Field Sample Container**	**Total Holding Time[b]**	**Field Preservation**	**Laboratory Preservation**	**Actual Reporting Limit/ Resolution**	**Target Reporting Limit/ Resolution**	**Units**
Grain size	Sieve and Pipette	ASTM D422	5-gallon bucket	6 months	Maintain ≤6°C	Maintain ≤6°C	NA	NA	%

[a] ASTM (2003).

[b] Holding time specified in the referenced methods.

°C = degrees Celsius

NA = not applicable

Surveying

Once annually during summer low-flow conditions, field crews will survey elevations at defined cross-sections at all monitoring locations. The crews will also survey erosion pins that were placed at each monitoring location to verify that the apex of the pins has not shifted. Where feasible, surveys will be tied into local benchmarks so that the surveys can be on the same datum as the base map for the watershed.

Turbidity Monitoring

Data from the turbidity sensor at each continuous monitoring station will be downloaded and the batteries changed every 3 weeks. At this time, the sensors will also be inspected to verify that the sensor is not fouling. Fouling of the sensor face is the most frequent source of error associated with field-deployed turbidity sensors. The turbidity data will subsequently be uploaded to Aquarius™ continuous data management database and stored with the water level data and rating curve results. See the *Data Analysis Procedures* section below for how these data will be used to assess sediment loading.

Documentation of Field Data Collection Activities

Field data collection activities will be recorded on custom field forms (Appendix B) during the collection of water samples, bedload samples, and discharge measurements. All field forms will be scanned and stored electronically; hard copies will be kept as backups. For all visits, station ID, location, sampling time, sampling date, and the sample collector's name are recorded. Data for manual discharge measurements will be recorded on a stream flow measurement data sheet in the field and will include water depth as measured at the staff gauge installed at each station. Detailed observational data from each station will be recorded including water appearance, weather, biological activity, unusual odors, specific sample information, missing parameters, days since last significant rainfall, and flow severity. Field forms will be filed and included with the final report for this project.

Additional details regarding field notes, sample identification, sample collection, and sample analysis can be found in the *Quality Control* section.

MEASUREMENT PROCEDURES

Laboratory analytical procedures for this project will follow methods approved by the US Environmental Protection Agency (US EPA) (ASTM 2003). These methods provide reporting limits that are low enough to assess water quality at low pollutant concentrations, and below the state and federal regulatory criteria or guidelines, which will allow comparison of the analytical results with these levels. The preservation methods, analytical methods, reporting limits, and sample holding times are presented in Tables 2 and 3.

Water samples will be analyzed for SSC (Table 2). SSC is reported as sediment concentration greater than 62.5 microns (sand and larger) and sediment concentration less than 62.5 microns (silt and smaller). Figure 7 provides the Wentworth scale for reference.

Bedload samples will be analyzed for grain size using ASTM D422 (Table 3). The following bins are reported as part of this method and can be referenced in Figure 7:

Size	Description
128,000 to 181,000 uM	cobble
90,500 to 128,000 uM	cobble
64,000 to 90,500 uM	cobble
45,300 to 64,000 uM	very coarse pebble
32,000 to 45,300 uM	very coarse pebble
22,600 to 32,000 uM	coarse pebble
16,000 to 22,600 uM	coarse pebble
11,300 to 16,000 uM	medium pebble
8,000 to 11,300 uM	medium pebble
5,700 to 8,000 uM	fine pebble
4,000 to 5,700 uM	fine pebble
2,800 to 4,000 uM	very fine pebbles
2,000 to 2,800 uM	very fine pebbles
1,000 to 2,000 uM	very coarse sand
500 to 1,000 uM	coarse sand
250 to 500 uM	medium sand
125 to 250 uM	fine sand
63 to 125 uM	very fine sand
31 to 63 uM	coarse silt
16 to 31 uM	medium silt
8 to 16 uM	fine silt
4 to 8 uM	very fine to fine silt
2 to 4 uM	clay
1 to 2 uM	clay
<1 uM	colloidal

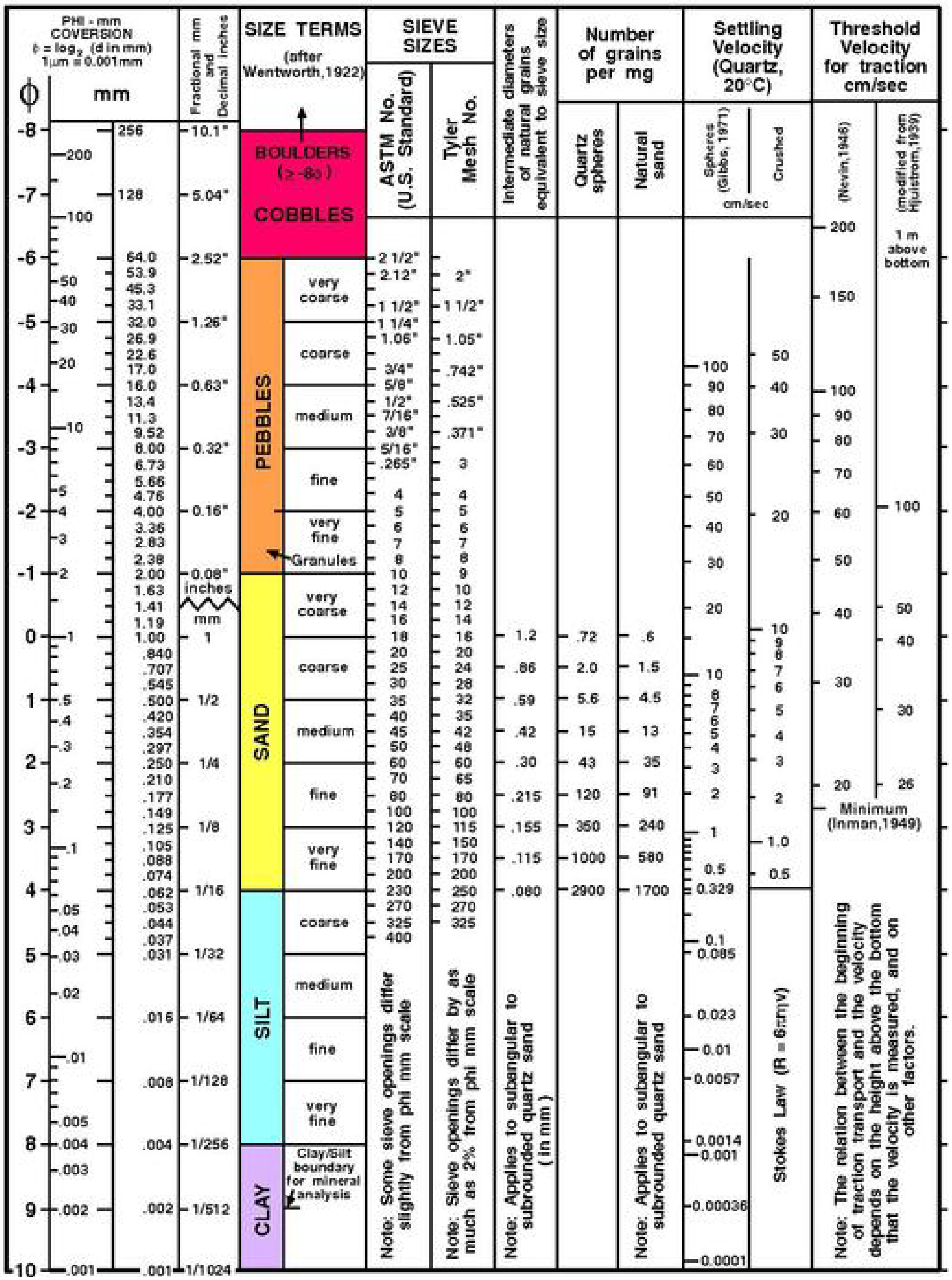

Figure 7. Wentworth (1922) Grain Size Chart (from Williams et al. 2006).

The laboratory identified for this project (AmTest, Inc.) is certified by Ecology for the methods requested and participates in audits and inter-laboratory studies overseen by Ecology and US EPA. These performance and system audits periodically verify the adequacy of the laboratory's standard operating procedures, which include preventive maintenance, data reduction, and quality assurance/quality control (QA/QC) procedures.

The laboratory will report the analytical results within 3 weeks of receipt of the samples. The laboratory will provide all sample and quality control data in standardized reports that are suitable for evaluating the project data, including electronic data deliverables (EDDs) formatted for upload to SPU's EQuIS™ database. Submittals will include all raw data, including but not limited to:

- All raw values including those below the reporting limit and between the method detection limit and the laboratory reporting limit,
- The laboratory method detection limits and reporting limits for all analytes for each batch, and
- All field duplicate and laboratory split results.

Data are to be submitted in compiled electronic format in Microsoft Excel spreadsheet and PDF format. The reports will also include a case narrative summarizing any problems encountered in the analyses. Sediment and water quality data will be provided to SPU in the SPU-EDD laboratory EDD format compatible with SPU's EQuIS database, as requested.

QUALITY OBJECTIVES

The goal of this SAP is to ensure that the data collected through the monitoring are scientifically accurate, useful for the intended analysis, and legally defensible. To achieve that goal, the collected data will be evaluated relative to the following indicators of quality assurance.

- **Precision:** A measure of the variability in the results of replicate measurements due to random error
- **Bias:** The systematic or persistent distortion of a measurement process that causes errors in one direction (i.e., the measured mean is different from the true value)
- **Representativeness:** The degree to which the data accurately describe the conditions being evaluated based on the selected sampling locations, sampling frequency and duration, and sampling methods
- **Completeness:** The amount of data obtained from the measurement system
- **Comparability:** The ability to compare data from the current study to data from other similar studies, regulatory requirements, and historical data

Measurement quality objectives (MQOs) are performance or acceptance criteria that are established for each of these quality assurance indicators. The MQOs are described below in separate subsections for hydrologic and laboratory data.

MEASUREMENT QUALITY OBJECTIVES FOR CONTINUOUS DATA

Continuous monitoring includes water level and turbidity monitoring. Stream flow measurement error can be introduced through two primary pathways: error associated with the rating curve and error associated with the water level sensors.

The data quality indicators for these measurements are expressed in terms of precision, bias, representativeness, completeness, and comparability. Assessments of precision and bias will be conducted before equipment is deployed in the field and again at the end of the project when the monitoring equipment is retrieved from the field. The MQOs for hydrologic monitoring are defined below.

Precision

The precision of the water level sensors used will be assessed by submerging the sensors in a 2-liter graduated cylinder covered with foil. The sensor reading will be recorded on a 5-minute time step for 4 hours at approximately 25 degrees Celsius. Subsequently, the coefficient of variation will be calculated using the following equation:

$$C_v \quad — \quad 100\%$$

Where: C_v = Coefficient of variation

σ = Standard deviation

μ = The average gauge reading

The MQO will be a C_v of no more that 5 percent.

Bias

Bias will be assessed based on a comparison of the water level sensor readings to an independently measured "true" value. To assess bias associated with the water level sensors, the sensors will be placed in a 2-liter graduated cylinder. The cylinder will be filled with water to three different known depths, and the resultant level readings from the sensor will be compared with the "true" measured values. Three readings will be recorded at each water level. The MQO for level measurements will be a difference of no more than 5 percent between the sensor's reading and the independently measured level values.

Bias in the turbidity sensor readings will be assessed by comparing the sensor reading to that of a known standard solution and subsequently calibrating the sensor. This procedure will be conducted before sensor deployment and monthly thereafter. If no sensor drift is noted after the first 3 months, the sensor calibration interval may be increased. This relatively infrequent sensor calibration for the YSI 600 OMS is appropriate because optical turbidity sensors with physical wipers are designed to be resistant to calibration drift.

Precision and bias associated with the rating curves will be assessed simultaneously by calculating a coefficient of variation (Cv) for the rating curve. The Cv is a measure of the variance in the data around the rating curve.

Representativeness

The representativeness of the flow and sediment data will be ensured by the proper installation of the monitoring equipment and use of standard water sample collection techniques. Sites will be selected in representative reaches for each stream segment (east fork, west fork, main stem) and sample collection points will be selected to best represent the reach conditions. High resolution continuous data collection—flow (5 minute) and turbidity (15 minute)—will help ensure the collected data best represents the actual environmental conditions in the channel.

Completeness

Completeness will be assessed based on occurrence of gaps in the data record for all monitoring equipment. The associated MQO is less than 10 percent of the total data record missing due to equipment malfunctions or other operational problems. Completeness will be ensured through routine maintenance of all monitoring equipment (see *Field Quality Control Procedures* section below) and the immediate implementation of corrective actions if problems arise.

Comparability

There is no numeric MQO for this data quality indicator. However, standard monitoring procedures, units of measurement, and reporting conventions will be applied in this study to meet the goal of data comparability.

Measurement Quality Objectives for Laboratory Data

Quality assurance indicators for laboratory data are expressed in terms of precision, bias, representativeness, completeness, and comparability. The specific MQOs that have been identified for this project are described below and summarized for the water and quality data in Tables 4 and 5. On an annual basis the data will be reviewed and flagged based on standard data validation methods using the MQOs in Tables 4 and 5 as guidance. Note that the term “reporting limit” in this document refers to the practical quantification limit established by the laboratory, not the method detection limit.

Table 4. Measurement Quality Objectives for Water Quality Data.

Parameter	Laboratory Method Blank[a]	Laboratory and Field Duplicate *RPD*[b]	Laboratory and Field Duplicate RSD_p[c]
Suspended sediment concentration	NA	£25% or ±2 ´ RL	£25%

[a] If criterion is not met, associated blank concentration is defined as the new reporting limit, and project sample data within 5 times this *de facto* reporting limit are flagged with a *J*.

[b] The relative percent difference must be less than or equal to the indicated percentage for values greater than 5 times the reporting limit. *RPD* must be and ±2 times the reporting limit for values less than or equal to 5 times the reporting limit.

[c] RSD_p will only be calculated for values that exceed 5 times the RL.

RSD_p = pooled relative standard deviation

RL = reporting limit

RPD = relative percent difference

Table 5. Measurement Quality Objectives for Sediment Quality Data.			
Parameter	**Laboratory Method Blank**	**Laboratory and Field Duplicate *RPD*[a]**	**Laboratory and Field Duplicate *RSD*$_p$[b]**
Grain size	NA	≤20% or ±2 × RL	≤35%

[a] The relative percent difference must be less than or equal to the indicated percentage for values that are greater than 5 times the reporting limit. *RPD* must be ±2 times the reporting limit for values that are less than or equal to 5 times the reporting limit.

[b] The pooled relative standard deviation will only be calculated for values that exceed 5 times the RL.

NA = not applicable.

RL = reporting limit.

RPD = relative percent difference.

RSD_p = pooled relative standard deviation.

Precision

In this study, data precision will be evaluated using analytical precision and total precision. The following sections describe the MQOs associated with each type of precision.

Total Precision

Total precision will be estimated using independent field duplicate samples and laboratory split samples. Overall project data quality will be based on total precision; but part of the process of determining data suitability will depend on analytical precision (see below) objectives being met.

For paired values that are both greater than 5 times the reporting limit, the pooled relative standard deviation (RSD_p) of laboratory and field duplicates will meet the MQO identified in Tables 4 and 5. When one or both values are less than or equal to 5 times the reporting limit, they will not be included in the RSD_p calculation.

The RSD_p of duplicate field samples will be calculated using the following equation:

$$\sqrt{\frac{Ci_1 \quad Cj_2{}^{2}}{2m}} \quad \text{and } RSD_p = \quad \frac{S_p}{\bar{x}} \quad 100\%$$

Where:

S_p	=	Pooled standard deviation
RSD_p	=	Pooled relative standard deviation
Ci_1 and Cj_2	=	Concentration values
m	=	Number of pairs

Since there is no advantage to randomly selecting samples for replication, all available information and professional judgment will be used to select samples or measurements likely to yield results above 5 times the reporting limit (Ecology 2004).

Analytical Precision

Analytical precision will be assessed based on laboratory splits of samples, matrix spikes, and laboratory control samples (see below, under *Bias*).

For paired values that are both greater than 5 times the reporting limit, the relative percent differences (RPD) of laboratory split samples will meet the MQO identified in Tables 4 and 5. If split sample values are both within 5 times the reporting limit, the RPD goal for all parameters is <2 times the reporting limit. If either of the split sample concentrations is at or below the reporting limit, the RPD will not be calculated.

The *RPD* will be calculated using the following equation:

$$RPD = \frac{\left| C_1 \quad C_2 \right|}{C_1 \quad C_2} \quad 200\%$$

Where: *RPD* = Relative percent difference

C_1 and C_2 = Concentration values

Bias

The SSC and grain size methods do not call for the assessment of laboratory blank or control standards; consequently, this MQO will not be assessed in the lab. However, bias in SSC values can be introduced from sampling. Specifically, SSC samples are being collect by automated sampling and grab sampling. Grab sampling occurs in the thalweg and near the surface while automated sampling occurs near the bed and typically offset from the thalweg. On five occasions staff will collect grab samples at the same time as automated samples (during storm events) for a comparison between 1) bank grab samples, 2) thalweg grab samples, and 3) automated samples. An MQO of no more than 20 percent variance between the samples will be used.

Representativeness

The experimental design will provide samples that represent a wide range of water quality conditions during storm flow. This will be achieved by collecting time paced samples over 12-hour periods to capture the rising, peak, and falling limb of the storm hydrograph. After each storm, field personnel will select 5 sample bottles from a total of 24 sample bottles collected at equal time steps during the storm based on a visual inspection of turbidity in the sample containers. Because the goal of the monitoring is to assess sediment transport, only events forecast for more than 0.35 inches of rain in a 12-hour period will be targeted. It is anticipated that storms producing rainfall totals above this threshold will have sufficient energy to mobilize sediment in the creek. Water sampling procedures will ensure representativeness of the collected samples by using aseptic technique, and sampling from the center and mid-depth of the stream channel.

Completeness

Completeness will be calculated by dividing the number of valid values by the total number of values. Valid sample data consists of unflagged data and estimated data that has been assigned a *J* qualifier. A qualitative assessment will be made as to which *J* flagged data may need to be excluded from this calculation before the production of the Final Report. If less than 95 percent of the samples submitted to the laboratory are judged to be valid, then additional samples will be collected until at least 95 percent are judged to be valid.

Comparability

Standard sampling procedures, analytical methods, units of measurement, and reporting limits (see Tables 2 and 3) will be applied in this study to meet the goal of data comparability. The results will be tabulated in standard spreadsheets to facilitate analysis.

QUALITY CONTROL

Quality control procedures are identified in separate subsections below for field and laboratory activities. The overall objective of these procedures is to ensure that data collected for this project are of a known and acceptable quality.

FIELD QUALITY CONTROL PROCEDURES

Quality control procedures that will be implemented for field activities are described in the following subsections. The frequency and type of quality control samples to be collected in the field are also summarized in Tables 6 and 7.

Table 6. Quality Assurance Requirements and Anticipated Number of Water Samples for Each Parameter.

Parameter	Samples per Station	Number of Stations	Total Number of Samples	Laboratory Method Blanks	Laboratory Control Standard	Field Duplicates	Lab Duplicates
Suspended sediment concentration	20	4	80	1/batch[a]	1/batch[a]	8[b]	1/batch[a]

[a] Laboratory QA samples will be analyzed with each batch of samples submitted to the laboratory for analysis. A laboratory batch will consist of no more than 20 samples.

[b] Field duplicates will be collected and analyzed for at least 5 percent of the total number of submitted samples.

Note: Numbers provided assume that a total of five storms will be monitored during the 12-month monitoring period.

Table 7. Quality Assurance Requirements and Anticipated Number of Sediment Samples for Each Parameter.

Parameter	Samples per Station	Number of Stations	Total Number of Samples	Laboratory Method Blanks	Laboratory Control Standard	Field Duplicates	Lab Duplicates
Grain size	10	4	40	1/batch[a]	1/batch[a]	0[b]	1/batch[a]

[a] Laboratory QA samples will be analyzed with each batch of samples submitted to the laboratory for analysis. A laboratory batch will consist of no more than 20 samples.

[b] The MEWI sample collection method does not allow for the practical collection of field duplicates.

Instrument Maintenance and Calibration

Before and after each targeted event, routine maintenance and operational inspections will be performed to ensure that the equipment is functioning properly. Maintenance activities and operational inspections will include:

- Inspection of battery voltage on the automated samplers
- Replacement of desiccant for the dataloggers and autosamplers
- Verify the accuracy of the aliquot pump volume
- Check the sample intake and sample line for clogs or leaks
- Verify the integrity of the stilling wells and staff gauges

The turbidity sondes will be calibrated approximately every month using a 2-point calibration with deionized water and a 126 Nephelometric turbidity unit (NTU) solution.

Field Notes

During each pre-, mid-, and post-storm site visit to each monitoring station, the following information will be recorded on a waterproof standardized field form (see Appendix B).

- Site name
- Date/time of visit and last sample collected
- Name(s) of field personnel present
- Weather and flow conditions, and significant recent events
- Desiccant condition
- Sampling errors? (if sampled)
- Unusual conditions (e.g., oily sheen, odor, color, turbidity, discharges or spills, and land disturbances)
- Note conditions that may be affecting level gauging stilling well (debris on well, debris on the downstream control, hydraulic jump around well, etc.)
- Modifications of sampling procedures
- MEWI information (water slope, flow rate, bedload collection information)
- Stream discharge data

Field notes will be included as an appendix in the Final Report produced for this project.

Field Duplicates

Field duplicates will be collected at a sufficient frequency to represent 10 percent of the total number of project samples analyzed. The number of field duplicates to be collected during the monitoring period is listed in Tables 6 and 7. For water quality samples, field duplicates will be collected by only when collecting grab samples because the automated samplers cannot accurately collect duplicate samples. No duplicates of the bedload samples will be collected because the MEWI method does not allow for the accurate splitting of samples for duplication.

All duplicate samples will be submitted to the laboratory and labeled as separate (blind) samples. The resultant data from these samples will then be used to assess variation in the analytical results that is attributable to environmental (natural), sub-sampling, and analytical variability.

Sample Handling

Automated samplers will be filled with ice before each sampled storm event. Ice will not be allowed to sit within autosamplers for more than 24 hours before the initiation of an event (with the goal of keeping sample temperatures below 6 degrees Celsius per ASTM D3977-97B). After each targeted storm event, all samples will be minimally processed in the field to prevent potential contamination from trace pollutants in the atmosphere.

All sample bottles selected for laboratory analysis will be transported in containers with ice and kept below 6 degrees Celsius until delivery to the laboratory. The temperature of the samples will be measured upon sample delivery and recorded on the chain of custody form (Appendix C).

Sample Identification and Labeling

All sample containers will be labeled with the following information using indelible ink and labeling tape:

- Site/station name (e.g., TC-EF or TC-WF)
- Date of sample collection (year/month/day: yyyy/mm/dd)
- Time of sample collection (international format [24 hour])
- Field personnel initials (e.g., DSA)

Quality assurance (QA) samples (field duplicates and blanks) will only be labeled as QA1, QA2, etc., for delivery to lab, but field staff will maintain a cross-check list of which stations and sample types the QA samples represent. When results are returned from the laboratory, the consultant will associate full label information with the results and populate database fields for QA sample and type.

Waterproof labels will be placed on dry sample container lids by self-adhesion or with tape. Waterproof labeling tape may be employed. Any written marks will be made with waterproof ink.

Sample Containers and Preservation

Clean, decontaminated sample bottles will be obtained from the analytical laboratory in advance of each storm event. Spare sample bottles will be carried by the sampling team in case of breakage or possible contamination. Sample containers and preservation techniques will follow US EPA (2007) guidelines. After samples are processed, laboratory personnel will clean the sample bottles with a four-step process: 1) Liquinox detergent rinse, 2) reagent grade water rinse, 3) two molar nitric acid rinse, 4) reagent grade water rinse.

Chain-of-Custody Record

A chain-of custody record (Appendix C) will be maintained for each sample batch listing the sampling date and time, sample identification numbers, analytical parameters and methods, persons relinquishing and receiving custody, dates and times of custody transfer, and temperature of sample upon delivery.

Laboratory Quality Control Procedures

Quality control procedures that will be implemented in the laboratory are described in the following subsections. The frequency and type of quality control samples to be analyzed by the laboratory are also summarized in Tables 6 and 7.

Method Blanks

Method blanks consisting of deionized and micro-filtered pure water will be analyzed with every laboratory sample batch. A laboratory sample batch will consist of no more than 20 samples and may include samples from other projects. The total number of method blanks anticipated for this study is shown in Tables 6 and 7 by parameter. Blank values will be presented in each laboratory report.

Control Standards

Control standards for each parameter will be analyzed by the laboratory with every sample batch. A laboratory sample batch will consist of no more than 20 samples and may include samples from other projects. The total number of control standards anticipated for this study is shown in Tables 6 and 7 by parameter. Raw values and percent recovery (see formula in the *Quality Objectives* section) for the control standards will be presented in each laboratory report.

Laboratory Duplicates (split project samples)

Laboratory split-sample duplicates for each parameter will be analyzed for specifically labeled QA samples submitted with every sample batch. This will represent no less than 10 percent of the project submitted samples. The total number of laboratory duplicates anticipated for this study is shown in Tables 6 and 7 by parameter. Raw values and relative percent difference (see formula in the *Quality Objectives* section) of the duplicate results will be presented in each laboratory report.

Discharge Measurement

A handheld velocity meter will be used to measure discharge at each of the monitoring stations following procedures outlined in the Flow Measurement Standard Operating Procedure (SOP) presented in Appendix A. These procedures are based on methods established by the US EPA for the Puget Sound Estuary Program (PSEP 1996) and require that the velocity meter is calibrated on an annual basis according to factory specifications. In addition, the sensor will be zeroed prior to each sampling round. This process involves placing the sensor in a bucket of quiescent water and resting the velocity reading to zero.

DATA MANAGEMENT PROCEDURES

The hydrologic data from each continuous monitoring station will be imported into a database (Aquarius™ data management software) for subsequent analysis and archiving purposes. These data will be immediately checked for evidence of an equipment malfunction or other operational problem. Gaps in flow data may need to be interpolated; if this occurs, data will be stored and presented in a manner that makes it clear which data are from measurement, and which have been interpolated. The database will be used to produce event based hydrologic summary statistics (e.g., station runoff volume, storm precipitation total, storm duration) for each applicable station. These summary statistics will ultimately be stored in a Microsoft Access database with other water quality data collected through the project (see description below).

The laboratory will report the analytical results within 30 days of receipt of the samples. The laboratory will provide sample and quality control data in standardized reports that are suitable for evaluating the project data. These reports will include all raw data including raw quality assurance data, and all quality control results associated with the data. The reports will also include a case narrative summarizing any problems encountered in the analyses, corrective actions taken, changes to the referenced method, and an explanation of data qualifiers. Laboratory analytical and QA results will be delivered from the laboratory in electronic format.

Analytical data for the project will be stored in a spreadsheet (Microsoft Excel) format with related event-based hydrologic data from each storm. A continuous hydrologic record will also be stored. The Herrera quality assurance officer will perform an independent review of the data to ensure that all sample values were entered without error. This review will consist of checking that all laboratory data were entered into the database correctly and all data in the database agree with the data presented in the report. Results from this review will be documented in a data entry review worksheet (Appendix C).

Sediment analytical data will also be provided to SPU in the SPU-EDD laboratory EDD format for management in SPU's EQuIS database. Data managed in EQuIS will be retained indefinitely.

Both the laboratory and Herrera will retain project related data for 5 years after completion of the project.

DATA ANALYSIS PROCEDURES

The following section describes the data analysis procedures that will be used in this monitoring.

HYDROLOGY

A summary table of manual discharge data will be presented for all the continuous monitoring stations along with the associated final rating curves. In addition, a storm summary table will be presented which provides summary statistics (e.g., peak discharge, storm volume, rain depth, antecedent dry period, etc.) for all the storm events that were captured through the monitoring at each station.

SUSPENDED SEDIMENT LOADING

Instantaneous areal suspended solids loading rates will be calculated for each of the four continuous monitoring stations to identify the relative contribution from the monitored drainage areas. To calculate instantaneous areal SSC loading rates, SSC concentrations for each sample will be multiplied by the measured stream discharge rate, and then divided by the sub-watershed area. Areal SSC loading rates will then be presented as box plots for each station. The SSC loading rates will be evaluated to determine if there are potential sediment export problem areas in the sub-watersheds of the study area.

Annual SSC loading for each continuous station will then be estimated using the rating curve approach described by Helsel and Hirsch (2002). Specifically, a linear regression model will be developed based on a log transformation of the measured SSC concentrations and the log transformed flow rates at the time of sampling. This model will allow SSC loadings for 5-minute periods (stream gage logging interval) to be estimated as a function of stream discharge. Because logarithmic data transformations are typically required to obtain a linear model from these data, a correction factor for transformation bias will be added to the models using the nonparametric smearing approach (Helsel and Hirsch 2002). The linear regression models will subsequently be applied to the continuous stream discharge data record to predict 5-minute SSC loading over the periods when no sampling took place. These 5-minute SSC loading estimates will then be summed to quantify SSC loadings for the entire monitoring period.

If statistically significant regression models (i.e., slope of regression line significantly different from zero with $\alpha < 0.10$) cannot be developed using the above approach, SSC loadings will be estimated by multiplying the mean concentration SSC by the annual volume of stormflow that was measured at each site per Phillips et al. (1999).

In addition to the method described above, an additional method will be used to estimate suspended solids loading. Specifically, linear regression models will be developed to predict SSC concentrations as a function of turbidity measurements from each sensor. The same smearing method described above will be used to develop a regression between SSC and turbidity. If this regression has a lower coefficient of variation than the regression between flow and SSC from the same location, then the former relationship will be used to estimate the annual suspend solids load for that station.

Bedload Flux

Bedload will be estimated at all monitoring stations using a site-calibrated Parker-Klingman gravel transport model (Bakke et al. 2017). During storm events a BLH-84 will be used to collect bedload samples at each monitoring station. The multiple equal-width-increment bedload sampling method (Edwards and Glysson 1999) will be used. This method consists of repeatedly placing a BLH-84 sequentially at four (or more) evenly-spaced locations across the cross-section of the stream for 30 sections in each section and repeating the process for 10 passes through the cross-section. The samples will provide data on the fractional sediment transport rate based on grain size (see *Measurement Procedures* section for gradations).

The Parker-Klingeman model computes bedload transport for each grain size at each point across the channel cross-section. Site calibrated models such as this are advantageous for hydraulically complex systems where a small number of bedload samples are available. These models have been shown to have the best overall accuracy with relatively minimal field effort and thus are implemented in this study. The Parker-Klingeman model will be calibrated at each monitoring station by adjusting several coefficients to result in the minimum average sum of square error between the model output and bedload samples. These adjusted coefficients govern the reference dimensionless shear stress for particle mobility. This model was originally created in FORTRAN (Bakke et al. 1999) but has since been successfully implemented using Python (Bakke et al. 2017). The Python implementation of this model will be used in this study. Overall, the model will use collected bedload samples in combination with continuous time series for discharge to compute a time series of bedload at each station within the system. For further information regarding the model, refer to Bakke et al. (1999; 2017).

Total Sediment Loading and Mass Balance

The final analysis will involve summing the bedload and suspended load values derived from the above analyses. These total sediment load results will be used to assess sediment sources in the watershed and to inform sediment loading to the future sediment control facility upstream of the Rainier Avenue South culvert.

Bedload flux from the upper stations (TC-EF and TC-WF) will be subtracted from bedload flux at TC-MID and SPU_STA401, to determine the bedload retained or lost in the reach between these stations. This analysis will be repeated for suspended solids and total sediment flux. To assess bedload flux between SPU_STA401 and TC-Mouth, the flux calculated at SPU_STA401 will be subtracted from the flux calculated at TC-Mouth. Suspend load is not being assessed at TC-Mouth at this point, so for the purposes of this SAP, only estimates of bedload flux will be made for the reach between SPU_STA401 and TC-Mouth.

Together these results will help inform where sediment is being either generated or retained in the watershed.

REPORTING PROCEDURES

Herrera will prepare a final report to document the activities described in this SAP. The final report will specifically include the following information:

- Introduction and project background
- A statement of the project objectives
- Analysis and data collection methods
- Study results and review of QA procedures
- Discussion of results and comparison to other local urban watersheds and relevant studies
- Conclusions

REFERENCES

APHA, AWWA, and WEF. 1992. Standard Methods for the Examination of Water and Wastewater. 18th edition. Edited by A.E. Greenberg, American Public Health Association; A.D. Eaton, American Water Works Association; and L.S. Clesceri, Water Environment Federation.

ASTM. 2003. Book of Standards. Volume 11.02 – Water and Environmental Technology: Water (II). American Society for Testing and Materials, International, West Conshohocken, Pennsylvania.

Bakke, P.D., P.O. Basdekas, D.R. Dawdy, and P.C. Klingeman. 1999. Calibrated Parker-Klingman Model for Gravel Transport. Hydraulic Engineering 125(6):657–660.

Bakke, P.D., L.S. Sklar, D.R. Dawdy, and W.C. Wang. 2017. The Design of a Site-Calibrated Parker–Klingeman Gravel Transport Model. Water 9(441):1–16.

Bergman, N., J.B. Laronne, and I. Reid. 2007. Benefits of Design Modifications to the Birkbeck Bedload Sampler Illustrated by Flash-Floods in an Ephemeral Gravel-Bed Channel. Earth Surface Processes and Landforms 32(2):317–328.

Ecology. 2004. Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies. Publication No. 04-03-030. Washington State Department of Ecology, Olympia, Washington.

Edwards, T.K., and G.D. Glysson. 1999. Field Methods for Measurement of Fluvial Sediment. United States Geological Survey, Reston, Virginia.

McMahon, P.L. 2013. Bedload Transport Sampling, Characterization and Modeling on a Southern Appalachian Ridge and Valley Stream. Doctoral dissertation, University of Tennessee, Tennessee.

McNamara, M.L., and T. Sullivan. 2007. Forest Service Channel Maintenance Flows in the Klamath Basin. Proceedings of the Forest Service National Earth Sciences Conference, San Diego, California, October 18–22, 2004. Portland, Oregon.

Phillips, J.M., B.W. Webb, D.E. Walling, and G.J.L. Leeks. 1999. Estimating the Suspended Sediment Loads of Rivers in the Lois Study Area Using Infrequent Samples. Hydrological Processes 13(7):1035–1050.

PSEP. 1996. Recommended Protocols for Measuring Selected Environmental Variables in Puget Sound. Prepared for US Environmental Protection Agency Region 10, Office of Puget Sound, by Puget Sound Estuaries Program, Olympia, Washington.

US EPA. 1983. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020. US Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

US EPA. 1984. Guidelines Establishing Test Procedures for the Analysis of Pollutants under the Clean Water Act; Final Rule and Interim Final Rule. CFR Part 136. US Environmental Protection Agency, Cincinnati, Ohio.

US EPA. 2007. 40 CFR Part 122, 136, 141, 143, 430, 455, and 456; Guidelines Establishing Test Procedures for the Analysis of Pollutants under the Clean Water Act; National Primary Drinking Water Regulations; and National Secondary Drinking Water Regulations; Analysis and Sampling Procedures; Final Rule. Federal Register. US Environmental Protection Agency, Washington, DC.

USGS. 1969. Discharge Measurements at Gaging Stations. In: T.J. Buchanan and W.P. Somers (Editors), Techniques of Water-Resources Investigations, Chapter A8. United States Geological Survey, Arlington, Virginia.

Wentworth, C.K. 1922. A scale of grade and class terms for clastic sediments: Journal of Geology v. 30:377–392.

Wilcock, P.R., and J.C. Crowe. 2003. Surface-based transport model for mixed-size sediment. Journal of Hydraulic Engineering 129(2):120–128.

Williams, S.J., M.A. Arsenault, B.J. Buczkowski, J.A. Reid, J.G. Flocks, M.A. Kulp, S. Penland, and C.J. Jenkins. 2006. Surficial Sediment Character of the Louisiana Offshore Continental Shelf Region: a GIS Compilation, Open-File Report 2006-1195. US Geological Survey, Woods Hole, Massachusetts.

WSDOT. 2006. Work Zone Traffic Control Guidelines. Publication M 54-44. Washington State Department of Transportation, Olympia, Washington.

APPENDIX A

Standard Operating Procedures

STANDARD OPERATING PROCEDURES

Instantaneous Discharge Measurement in Streams and Pipes

SOP No. XXXX

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Tables

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1.0 Introduction, Scope and Applicability

This document describes Herrera Environmental Consultants' Standard Operating Procedures (SOP) for collecting discharge measurements in streams and pipes. It incorporates the USGS approved method (USGS 1969) for measuring discharge in channels and an adapted version for measuring discharge in pipes. Supplementary criteria and procedures are tailored from the "Recommended Protocols for Measuring Conventional Water Quality Variables and Metals in Fresh Water of the Puget Sound Region" (PSEP 1996). Additionally, a method for the use of a top-setting wading rod is presented. Appendices to this SOP include methods for the use of three types of velocity meters used by Herrera Environmental Consultants: a Marsh McBirney Flo-Mate Model 2000 Portable Flowmeter, a Swoffer Model 2100-13 propeller velocity meter, and an Aquacalc Model #1205 mini pygmy velocity meter.

2.0 Training

The procedures in this SOP are for use only by personnel who have received specific training and demonstrated a minimum level of competency. Documentation of training will be kept on file and be readily available for review.

3.0 General Considerations

Because cross sectional profile and velocity gradients are not uniform across pipes and channels it is necessary to compartmentalize the cross sectional area and measure an average velocity within each compartment. The method presented herein describes how to divide the cross section into compartments, how to estimate an average velocity within each compartment, and how to use this information to calculate discharge.

4.0 Equipment and Supplies

Each of the method described in this SOP must be conducted with appropriate field equipment. Table 1 provides a list of field equipment and identifies the equipment required for each flow measurement method.

5.0 Procedures

5.1 Stream Discharge Measurement Procedures

The procedures below are adapted from the "Recommended Protocols for Measuring Conventional Water Quality Variables and Metals in Fresh Water of the Puget Sound Region" (PSEP 1996) and the "Discharge Measurements at Gaging Stations" (USGS 1969).

Table 1. Required equipment for each flow measurement method.

Required Equipment	Pipe			Stream
	Velocity and Depth	Depth and Slope	Calibrated Bucket	Mid-section Velocity
Flow measurement SOP	✓	✓	✓	✓
Field notebook/form, clipboard and pen	✓	✓	✓	✓
Clock with stopwatch	✓	✓	✓	✓
Velocity meter [a]	✓			✓
Wading rod	✓			✓
Measuring tape/ruler	✓	✓		✓
Anchors (spikes) and clips				✓
Four-foot straight edge and bubble level		✓		
Calibrated bucket			✓	

[a] Descriptions and operating procedures of the various approved velocity meters are provided in appendix A

5.1.1 Site Selection Criteria

It is important to select a representative location to establish a station for monitoring discharge. Proper site selection will improve the accuracy of flow measurements at all stream discharge levels. The following criteria should be considered when establishing a discharge measurement station. However, it is rarely possible to meet all the criteria listed. Be aware of the limitations of the site selected and possible effects on measurement.

5.1.1.1 Stream Reach Criteria

The station should be located in a stream reach (i.e., longitudinal section of the stream) with the following characteristics:

- The stream should be relatively straight and free flowing upstream and downstream of the monitoring location.
- Flow should be confined to one channel at all stages of discharge (i.e., there should be no surface or subsurface bypasses).
- Streambed should be subject to minimal scour and relatively free of plant growth.
- Streambanks should be stable, high enough to contain maximum flows, and free of brush.
- The station should be located a sufficient distance upstream so that flow from tributaries and tides does not affect stage/discharge measurements.
- All discharge stages should be measurable somewhere within the reach. It is not necessary to measure low and high flows at the identical cross section.
- The site should be readily and safely accessible.

5.1.1.2 Cross Section Criteria

The cross section in which a station is located within a stream reach should have the following characteristics:

- Streambanks should be relatively high and stable.
- The stream should be straight with parallel banks.
- Depth and velocity must meet minimum requirements of the method and instruments being used.
- The streambed should be relatively uniform with a minimal number of boulders and without heavy aquatic growth.
- Flow should be uniform and free of eddies, slack water, and excessive turbulence.
- Sites should not be located downstream of areas with rapid changes in stage or velocity.

5.1.2 Stream Flow Measurement Procedures – Mid-Section Velocity Method

1. Check that the current meter is functioning properly (see Appendix A).

2. Extend a measuring tape at right angles to the direction of flow and measure the width of the cross section. Record measurements on a data sheet. Leave the tape strung across the stream.

3. Divide the width into segments using at least 20 points of measurement. If previous flow measurements have shown uniform depth and velocity, fewer points may be used. *Smaller streams may also require fewer points.* Measuring points should be closer together where depths or velocities are more variable. Cross sections with uniform depth and velocity can have equal spacing.

4. Record the distance from the initial starting bank and the depth at each observation point.

5. Record the current velocity at each observation point (see Figure 1). Horizontal (from right to left bank) and vertical (top to bottom) variation of stream velocity may influence stream flow measurements. To correct for vertical differences, hydrologists have determined depths that can yield acceptable estimates of the mean velocity over a vertical profile. If the depth exceeds 0.8 m (2.5 feet), it is recommended that velocities be measured at 20 percent and 80 percent of full depth and averaged to estimate mean velocity. In the depth range 0.1-0.8 m (0.3-2.5 feet), take the velocity at 60 percent of the full depth (measured from the surface) as

an estimate of the mean over the profile. Measuring velocity in water shallower than 0.1 m (0.3 feet) is difficult with conventional current meters. If much of the reach of interest is very shallow, or flow is too slow for current meter measurement, consider installing a control section and V-notch weir.

6. Use Equation 1 to calculate total stream discharge.

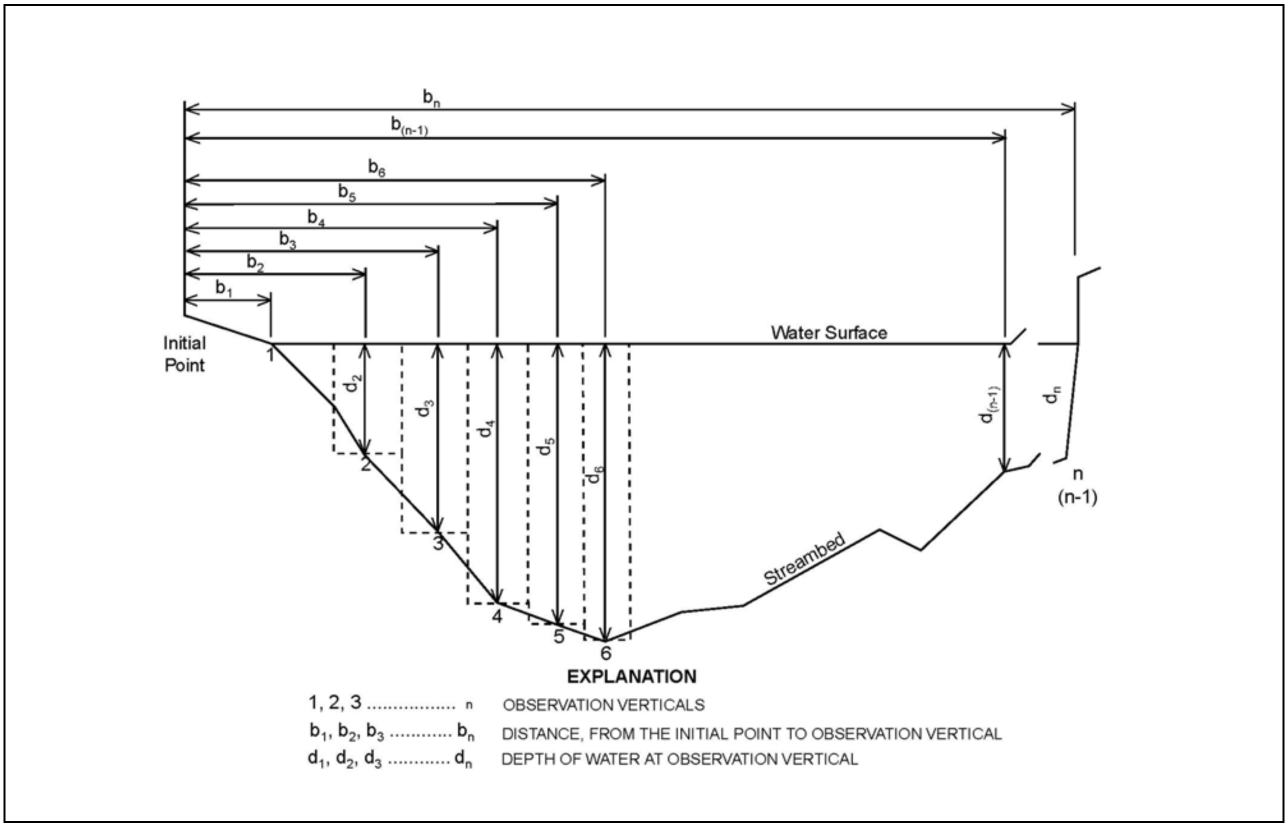

Figure 1. Sketch of midsection method of computing cross section area for discharge measurements.

Calculate flow as a summation of flows in partial areas using the following equation:

Equation 1

$$Q_n = V_n \times d_n \left(\frac{b_{n+1} - b_{n-1}}{2} \right)$$

Where: b_{n-1} = distance from initial point to the preceding point (m or ft)

b_{n+1} = distance from the initial point to the following point (m or ft)

d_n = mean depth at location n (m or ft)

V_n = mean velocity at location n (m/sec or ft/sec)

Q_n = discharge through partial section n (m^3/sec or ft^3/sec).

5.1.3 High Flow Stream Discharge Measurement Method

Streams should only be waded when the field technician's safety is assured. If a stream is deemed unwadeable then alternated methods are required to estimate stream discharge. When measuring discharge during elevated flow conditions, the following method should be employed:

1. Locate a nearby bridge.
2. Depending upon traffic conditions, weather, and bridge geometry traffic control measures should be employed to assure field technician and driver safety.
3. Extend a measuring tape at a right angle to the direction of flow and measure the width of the cross section. Record measurements on a data sheet. Leave the tape strung along the bridge railing.
4. Divide the width into segments using at least 20 points of measurement. If previous flow measurements have shown uniform depth and velocity, fewer points may be used. Smaller streams may also require fewer points. Measuring points should be closer together where depths or velocities are more variable. Cross sections with uniform depth and velocity can have equal spacing.
5. Record the distance from the initial starting bank and the depth.
6. Lower a graduated extension rod with attached velocity meter until the rod touches the surface of the water. Record distance on the rod. Lower rod until the rod touches the bed of the stream. Record distance on the rod. Subtract the two measure distance and multiply by 0.6 to determine the 60% depth level. Lower rod to 60% depth and record velocity.
7. Repeat process for each increment and then use Equation 1 to calculate discharge.

5.2 Pipe Discharge Measurement Procedures

The procedures below are adapted from the "Recommended Protocols for Measuring Conventional Water Quality Variables and Metals in Fresh Water of the Puget Sound Region" (PSEP 1996).

5.2.1 Site Selection Criteria

Site selection is of primary importance when measuring discharge. The majority of flow measurements in pipes will be conducted at outfalls or within catch basins. A rule of thumb is that velocity and depth measurements should be made upstream of the outfall at a distance equivalent to 5 times the depth at the outfall. This is to avoid the complex hydraulic conditions near the outfall that may affect the discharge calculation results.

5.2.2 Pipe Measurement Procedures

Flow in pipes is determined by one of the following methods:

- Velocity and depth method
- Depth and slope method
- Calibrated bucket method.

5.2.2.1 Velocity and Depth Method

Velocity (V) and depth (h) is measured in unobstructed pipes at the mid-point of the pipe. Velocity is measured with a current meter positioned at 60 percent of the water depth. Depth of flow is measured with the current meter or a ruler positioned in parallel to flow. The inside pipe diameter is measured by measuring across the center of the pipe. If flow depth is less than the radius of the pipe, flow area is determined according to equations 2 and 3.

Equation 2

$$A = \frac{r^2(\theta - \sin\theta)}{2}$$

Where: A = flow area

r = radius of the pipe

θ is defines in equation 3.

Equation 3

$$\theta = 2\arccos\left(\frac{r-h}{r}\right)$$

Where: h is flow depth.

If flow depth is greater than the radius of the pipe then equation 4 is used to calculate flow area.

Equation 4

$$A = \pi r^2 - \left(\frac{r^2(\theta - \sin\theta)}{2}\right)$$

Flow (Q) is calculated as the product of flow area (A) and velocity (V).

5.2.2.2 Depth and Slope Method

The depth and slope method of pipe flow measurement is employed when velocity cannot be measured. This method requires measurements of depth of flow, the inside pipe diameter, and pipe slope.

Slope of the pipe is measured by placing a four foot straight edge in the end of the pipe. A bubble level is placed on the straight edge and the straight edge is adjusted until level. The distance from the bottom of the straight edge to the inside base of the pipe is then measured. The slope is then determined by dividing the rise by the run. Flow is calculated according to Manning's equation, as follows:

Equation 5

$$Q = \frac{1.49}{N} \times R^{2/3} \times S^{1/2}$$

Where: Q = Flow in ft^3/sec

R = Hydraulic radius determined form depth of flow and pipe diameter (see Appendix B)

S = Pipe slope of the difference between pipe-invert elevation 9 feet) divided by the distance between measuring points

n = Roughness coefficient (see Table 2).

Table 2. Manning 'n' values for various types of culverts (pipes).

Type of Culvert	Roughness of Corrugation	Manning 'n'
Concrete Pipe	Smooth	0.010 - 0.011
Concrete Box	Smooth	0.012 - 0.015
Spiral Rib Metal Pipe	Smooth	0.012 - 0.013
Corrugated Metal Pipe, Pipe Arch and Box (Annular and Helical Corrugations - See Figure B-3, page 130, Manning 'n' varies with barrel size)	68 x 13 mm Annular 68 x 13 mm Helical 150 x 25 mm Helical 125 x 25 mm 75 x 25 mm 150 x 50 mm Structural Plate 230 x 64 mm Structural Plate	0.022 - 0.027 0.011 - 0.023 0.022 - 0.025 0.025 - 0.026 0.027 - 0.028 0.033 - 0.035 0.033 - 0.037
Corrugated Polyethylene	Smooth	0.009 - 0.015
Corrugated Polyethylene	Corrugated	0.018 - 0.025
Polyvinyl Chloride (PVC)	Smooth	0.009 - 0.011

Adapted from FHWA(2001)

5.2.2.3 Calibrated Bucket Method

The calibrated bucket method of pipe flow measurement is useful for low flows at pipe outfall locations. This method involves measuring the amount of water (to the nearest tenth of a gallon) that collects in a bucket placed under the outfall for a specific time period (seconds). Flow (gallons/minute or GPM) is calculated by dividing the volume (gallons) by the duration of collection (seconds) and multiplying by 60 seconds. Flow measurements should be taken over a period of at least 10 seconds.

6.0 Records and Documentation:

There are no specific quality assurance (QA) activities which apply to the implementation of these procedures. However, the following general quality control (QC) procedures apply:

All field conditions must be documented on field data sheets/ forms or within site logbooks. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling or operation and they must be documented.

7.0 Health and Safety

When working with potentially hazardous materials, follow U.S. EPA, OSHA and corporate health and safety procedures.

In streams of significant flow, the person performing the discharge measurements should be on a lifeline and wear adequate protective equipment. If flows are sufficiently high discharge measurements should be taken from a nearby bridge using appropriate methods.

8.0 References

Bureau of Reclamation. 2001. Water Measurement Manual. Chapter 10: Current Meters. http://www.usbr.gov/pmts/hydraulics_lab/pubs/wmm/chap10_08.html

CA DPR. 2004. Standard Operating Procedures. Procedure for Determining Wadable Stream Discharge with Price Current Meters. California Department of Pesticide Regulation. Environmental Monitoring Branch. Sacramento, California.

FHWA. 2001. Hydraulic Design of Highway Culverts, Second Edition. FHWA –NHI- 01-020, Federal Highways Administration, Washington, DC.

JBS Instruments Company. 2005. AquaCalc Pro Stream Flow Computer Instruction Manual. West Sacramento, California.

Marsh McBirney. 1990. Flo-Mate Model 2000 Portable Flowmeter Instruction Manual. Frederick, Maryland.

PSEP. 1996. Recommended Protocols for Measuring Selected Environmental Variables in Puget Sound. Prepared for U.S. Environmental Protection Agency Region 10, Office of Puget Sound, by Puget Sound Estuaries Program, Olympia, Washington.

Scientific Instruments, Inc. Instruction and Care Manual, Part No. 1205-66 and 1210-66, Milwaukee, Wisconsin.

Swoffer Instruments, Inc. Wand Operations Instructions Model 2100-13. From http://www.swoffer.com/manuals.htm accessed July 5, 2008.

USGS. 1969. Discharge Measurements at Gaging Stations. In: T.J. Buchanan and W.P. Somers (Editors), Techniques of Water-Resources Investigations, Chapter A8. United States Geological Survey, Arlington, Virginia.

STANDARD OPERATING PROCEDURE

BLH-84 SAMPLING

Prepared by
Herrera Environmental Consultants, Inc.
2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121
Telephone: 206-441-9080

DRAFT
2/16/2021

BEDLOAD SAMPLING

Introduction

Bedload refers to the portion of the total sediment load of a system that moves by sliding, rolling, or bouncing (i.e., saltating) along the streambed (Figure 1). Even under steady-state conditions, bedload discharge is extremely variable temporally and spatially. This variability is further magnified with rapid stage changes that are common in urban systems. Bedload discharge comes cyclically in waves making it difficult to capture representative data without collected numerous samples over a relatively extended period. Its therefore highly important that bedload samples are collected following the methods described here.

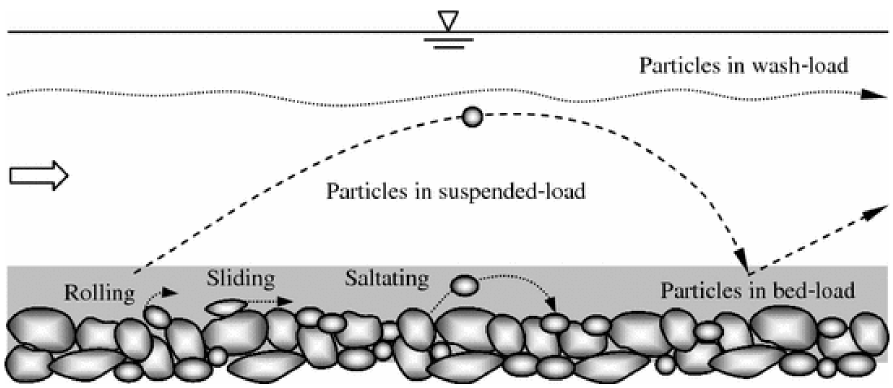

Figure 1. Bedload Transport (Dey 2014)

Method

The method described here to sample bedload is referred to as the Multiple Equal-Width-Increment Method (MEWI) (Figure 2). This method consists of collecting 4 samples evenly spaced across the width of the channel. The sampler (see details below) is held for 30 seconds at each position. Once the cross section is complete, the sampler is returned to the first of the four positions and the process is repeated, for a total of 10 cross sections. After each set of 4 samples (one cross section), the sampler is emptied into a composite bag. At the end of the 10 repeated cross sections there should be 40 subsamples in the composite bag. It is estimated that this process will take 30 minutes at each monitoring location.

With bedload being a function of water velocity, its required that flow measurements be taken at the same time as bedload. However, logistically this cannot feasibly be done without interfering with sediment collection. Thus, cross section of flow should be conducted at before and after bedload is sampled.

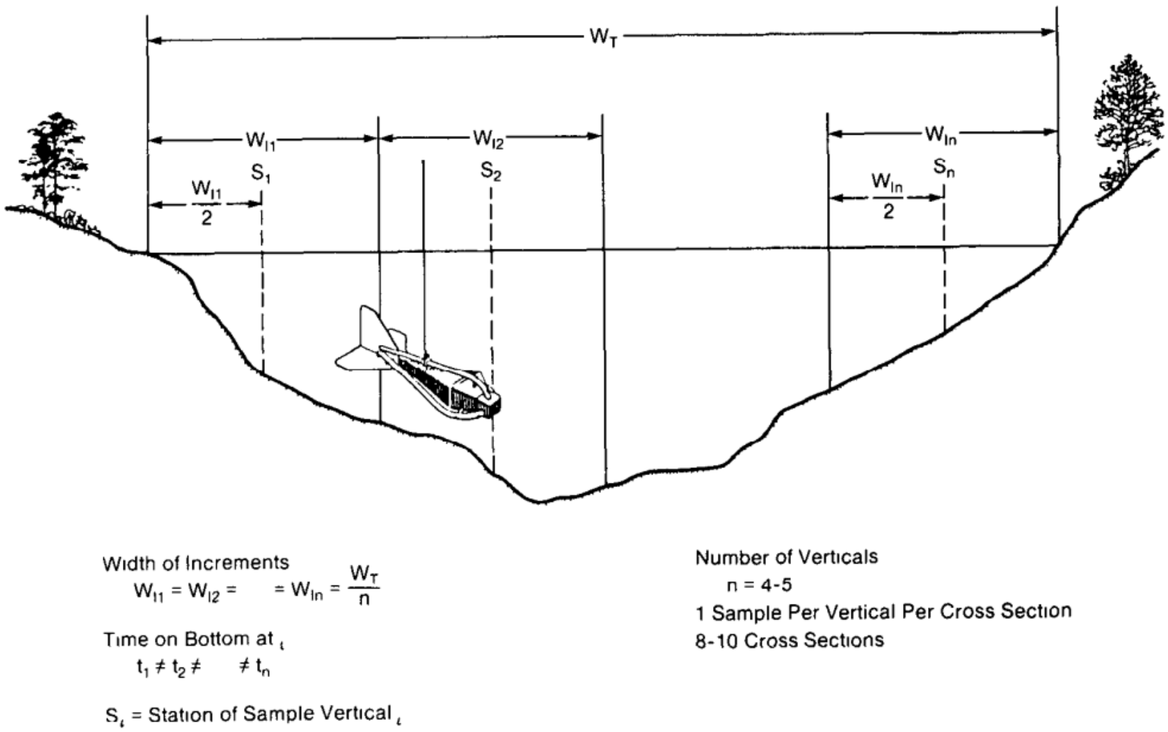

Figure 2. Multiple equal-width-increment bedload-sampling method (Edwards and Glysson 1970)

Sampler: BLH-84

The sampler is a Helley-Smith Sampler (BLH-84) that is a common tool for measuring bedload (Figure 3). The sampler should be placed flat on the streambed with the opening facing upstream. As sediment passes though the opening it is trapped in the attached net. To empty the sample, the bag is removed, and sediment emptied into the composite bag.

Figure 3. Helley-Smith Sampler (BLH-84)

Equipment List

- BLH-84
- Flow Meter
- Bedload Field Form
- Bag for Bedload Sample
- Stadia rod

Procedure

1. Extend stadia rod across the width of the stream perpendicular to the flow; Note the total width (W_T)

2. Divide W_T by 5 to obtain the width increment. This resulting in 4 equally spaced sampling locations (S_n) that are representative of 4 sections of the channel. For example, if W_T = 10′ then each width increment is 2′ resulting in a sampling location at 2′, 4′, 6′, and 8′ from the reference bank.

3. Prior to taking bedload samples, flow measurements should be taken across the stream channel using the SOP for the specific method/instrument used.

4. In the stream, place the BLH-84 at the first sampling location flat on the streambed with the opening facing upstream. Avoid scooping or disturbing any sediment in this process. Make sure to stand well downstream of the sampler so as not to disturb and sediment near the sampler opening.

5. Hold the bedload sampler in this position for 30 seconds.

6. Repeat steps 4-5 for the three remaining cross section positions.

7. After the cross section has been completed, empty the sampler net into the composite bag.

8. If the BLH-84 net is 1/3 full or less, then there is no need to empty the net at the end of the cross section.

9. Repeat the process nine more times for obtain the 40 total measurements required.

10. After all samples have been collected, take another set of flow measurement to evaluate the change in discharge that occurred through the sampling time.

11. Measure the water surface slope by measuring from the top of the reference pins installed in the channel to the water surface. One pin is located upstream of the cross section and one downstream.

Bedload Discharge Calculations

Bedload discharge should be computed using the total cross-section method (Edwards and Glysonn 1970). To do so, the following conditions must be met.

1. The sample times at each vertical are equal.

2. The verticals were evenly spaced across the cross section.

3. The first sample was collected at one-half the sample width from the starting bank.

The equation below should be used to calculate a discharge rate.

$$Q_B = \frac{W_T}{N_w}\frac{M_i}{t_T}$$

Q_B = Bedload discharge, as measured by bedload sampler (grams/second)

W_T = Total width of steam from which samples were collected (feet)

N_w = Width of the sampler nozzle (feet)

M_T = Total mass of sample collected from all verticals sampled in the cross section (grams)

t_T = Total time the sampler was on the bed, in seconds, computed by multiplying the individual sample time by the total number of samples (seconds)

APPENDIX B

Field Forms

FIELD LOG SHEET

Project Name:
Taylor Creek Flow and Sediment Monitoring

Site Location: Taylor Creek

Event ID:

Pre-Storm Visit

Date:	Time:			
	SPU-STA401	TC-EF	TC-WF	TC-LM
Sampler Battery Volt. (V):				
Actual Pump Vol (ml):				
Pump Vol Before Adj. (ml):				
Pump Vol After Adj. (ml):				
Intake Checked?	*Yes No*	*Yes No*	*Yes No*	*Yes No*
Desiccant Dry?	*Yes No*	*Yes No*	*Yes No*	*Yes No*
Sample Line Rinsed?	*Yes No*	*Yes No*	*Yes No*	*Yes No*
Pacing (minutes):				
Ice Added?	*Yes No*	*Yes No*	*Yes No*	*Yes No*
Program Started?	*Yes No*	*Yes No*	*Yes No*	*Yes No*
Tubing Connected?	*Yes No*	*Yes No*	*Yes No*	*Yes No*
Turbidity sensor checked?	*Yes No*	*Yes No*	*Yes No*	*Yes No*
Flow Conditions:	*Rise Peak Fall None*	*Rise Peak Fall None*	*Rise Peak Fall None*	*Rise Peak Fall None*

Notes/Visual Conditions: (if 'no' to any questions above, explain why and remedial actions taken)

Post-Storm Visit

Date:	Time:			
	SPU-STA401	TC-EF	TC-WF	TC-LM
Date/Time End:				
# of Samples:				
Sampled Without Error?	*Yes No*	*Yes No*	*Yes No*	*Yes No*
Est. Sample Vol (L):				
select 5 bottles to characterize				
time of selected bottle 1:				
time of selected bottle 2:				
time of selected bottle 3:				
time of selected bottle 4:				
time of selected bottle 5:				
Peak turbidity bottle time:				
5 bottles sent to Lab?	*Yes No*	*Yes No*	*Yes No*	*Yes No*
Duplicate Sample?	*Yes No*	*Yes No*	*Yes No*	*Yes No*
Flow Conditions:	*Rise Peak Fall None*	*Rise Peak Fall None*	*Rise Peak Fall None*	*Rise Peak Fall None*

Notes/Visual Conditions: (if 'no' to any questions above, explain why and remedial actions taken)

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Herrera - Taylor Creek - Stream Flow Data Sheet

Date:	Gauge Start Height:	Station (circle one): TC-EF TC-WF
Observer Initials:	Start Time:	TC-LM 401 TC-MO
	Gauge End Height:	Method: Wading / Culvert
	End Time:	

Gauging Assessment: Circle One *(within _% deviation from actual discharge)

Excellent (2%*) Good (5%*) Fair (8%*) Poor (10%*)

Comments (e.g. turbulence around gauge, lots of material in water, etc.):

Sketch (plan):	Sketch (cross-x):

Photo of Staff Gauge? yes no

Weather:

Measurement Data		RB Distance (ft):		LB Distance (ft):	
Horizon. Dist. (ft)	Water Depth (ft)	Velocity (ft/sec)	Horizon. Dist. (ft)	Water Depth (ft)	Velocity (ft/sec)
1			19		
2			20		
3			21		
4			22		
5			23		
6			24		
7			25		
8			26		
9			27		
Time / SG:			Time / SG:		
10			28		
11			29		
12			30		
13			31		
14			32		
15			33		
16			34		
17			35		
18			36		
Time / SG:			Time / SG:		

Flow (cfs):	Entered into Taylor Creek Database? Date: Initials:

Herrera - Taylor Creek EF - Stream Flow Data Sheet

Flow Station #:	Gauge Start Height:	Stream: **Taylor Creek EF**
Date:	Start Time:	Client: SPU
Observer Initials:	Gauge End Height:	Method: **Wading** / Culvert
	End Time:	

Gauging Assessment: Circle One *(within _% deviation from actual discharge)

Excellent (2%*) Good (5%*) Fair (8%*) Poor (10%*)

Flow Comments (e.g. turbulence around gauge, lots of material in water, etc.):

Cross Section Location:

Sketch of XS Location:

Control Feature/Condition:

Weather:

Notes (e.g. equipment problems, flow blockages, unusual stream conditions, etc.):

Measurement Data		RB Distance (ft):		LB Distance (ft):	
Horizon. Dist. (ft)	Water Depth (ft)	Velocity (ft/sec)	Horizon. Dist. (ft)	Water Depth (ft)	Velocity (ft/sec)
1			19		
2			20		
3			21		
4			22		
5			23		
6			24		
7			25		
8			26		
9			27		
Time / SG:			Time / SG:		
10			28		
11			29		
12			30		
13			31		
14			32		
15			33		
16			34		
17			35		
18			36		
Time / SG:			Time / SG:		

Flow (cfs):	Entered into Taylor Creek Database? Date: Initials:

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APPENDIX C

Quality Assurance Forms

HERRERA
2200 Sixth Avenue | Suite 1100
Seattle, Washington | 98121
p 206 441 9080 | f 206 441 9108

Chain of Custody Record

Project Name:	Project Number:	Client:
Taylor Creek Flow and Sediment Monitoring	17-06530-005	Herrera Environmental
Report To: Dylan Ahearn / Jennifer Arthur		Page: 1/1
Sampled By:		Delivery Method:
Laboratory: AMTest, Inc	Requested Completion Date:	Total No. of Containers:
Lab Use:		

Analyses Requested

Sample ID (ex. TC-WF-yyyymmdd-HH:MM)	Date	Time	Sample Type (see codes)	Sample Method (see codes)	Matrix (see codes)	Suspended Sediment Concentration – SM D3977-97B											
TC-WF-			PES	GRB-A	SW	X											
TC-WF-			PES	GRB-A	SW	X											
TC-WF-			PES	GRB-A	SW	X											
TC-WF-			PES	GRB-A	SW	X											
TC-WF-			PES	GRB-A	SW	X											
TC-EF-			PES	GRB-A	SW	X											
TC-EF-			PES	GRB-A	SW	X											
TC-EF-			PES	GRB-A	SW	X											
TC-EF-			PES	GRB-A	SW	X											
TC-EF-			PES	GRB-A	SW	X											
TC-401-			PES	GRB-A	SW	X											
TC-401-			PES	GRB-A	SW	X											
TC-401-			PES	GRB-A	SW	X											
TC-401-			PES	GRB-A	SW	X											
TC-401-			PES	GRB-A	SW	X											
TC-LM-			PES	GRB-A	SW	X											
TC-LM-			PES	GRB-A	SW	X											
TC-LM-			PES	GRB-A	SW	X											
TC-LM-			PES	GRB-A	SW	X											
TC-LM-			PES	GRB-A	SW	X											
TCD-			FDS	GRB-A	SW	X											
TCD-			FDS	GRB-A	SW	X											

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Seattle, Washington | 98121
p 206 441 9080 | f 206 441 9108

Chain of Custody Record

Project Name:	Project Number:	Client:
Taylor Creek Flow and Sediment Monitoring	17-06530-005	Herrera Environmental

Report To:	Page:
Dylan Ahearn / Jennifer Arthur	1/1
Sampled By:	Delivery Method:

Laboratory:	Requested Completion Date:	Total No. of Containers:
AMTest, Inc		

Lab Use:

Sample ID (ex. TC-WF-yyyymmdd-HH:MM)	Date	Time	Sample Type (see codes)	Sample Method (see codes)	Matrix (see codes)	Analyses Requested: Suspended Sediment Concentration – SM D3977-97B											

Comments/Special Instructions:

Relinquished by (Name/CO/	Signature	Date/Time		Received By (Name/CO)	Signature	Date/Time

Sample Type: PES= Primary Environmental Sample FSS= field duplicate sample **Sample Method:** GRB-A= Grab Automatic GRB-M= Grab Manual **Matrix Codes:** GW=Groundwater SE=Sediment SW=Surface Water W=Water (blanks) M=Material O=Other (specify)

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Seattle, Washington | 98121
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Chain of Custody Record

Project Name: Taylor Creek Flow and Sediment Monitoring	Project Number: 17-06530-005	Client: Herrera Environmental
Report To: Dylan Ahearn / Jennifer Arthur		Page: 1/1
Sampled By:		Delivery Method:
Laboratory: AMTest, Inc	Requested Completion Date:	Total No. of Containers:
Lab Use:		

Analyses Requested

Sample ID (ex. TC-WF-Bed-YYYYMMDD)	Date	Time	Sample Type (see codes)	Sample Method (see codes)	Matrix (see codes)	Grain Size - ASTM D422 and total sample dry weight											
TC-WF-BLHBed-			PES	SED-T	SE												
TC-EF-BLHBed-			PES	SED-T	SE												
TC-LM-BLHBed-			PES	SED-T	SE												
TC-401-BLHBed-			PES	SED-T	SE												
TC-Mouth-BLHBed-			PES	SED-T	SE												

Comments/Special Instructions:

In addition to ASTM D422 we need the dry weight of each entire sample that we submit. Please call 206-407-9538 if you have any questions. Provide data in SPU EDD format.

Please follow the following size scale of bed material grain size (mm):

0.001, 0.002, 0.004, 0.008, 0.016, 0.031, 0.063, 0.125, 0.25, 0.5, 1.0, 2.0, 2.8, 4.0, 5.7, 8.0, 11.3, 16.0, 22.6, 32.0, 45.3, 64, 90.5, 128, 181, 256

Relinquished by (Name/CO/	Signature	Date/Time		Received By (Name/CO)	Signature	Date/Time
Relinquished by (Name/CO/	Signature	Date/Time		Received By (Name/CO)	Signature	Date/Time

Sample Type: PES= Primary Environmental Sample FSS- Field Split Sample **Method Type:** SED-T= sediment trap **Matrix Codes:** GW=Groundwater SE=Sediment SW=Surface Water W=Water (blanks) M=Material O=Other (specify)

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Chain of Custody Record

Project Name: Taylor Creek Flow and Sediment Monitoring	Project Number: 17-06530-005	Client: Herrera Environmental
Report To: Dylan Ahearn / Jennifer Arthur		Page: 1/1
Sampled By:		Delivery Method:
Laboratory: AMTest, Inc	Requested Completion Date:	Total No. of Containers:
Lab Use:		

Analyses Requested

Sample ID (ex. TC-WF-Bed-YYYYMMDD)	Date	Time	Sample Type (see codes)	Sample Method (see codes)	Matrix (see codes)	Grain Size - ASTM D422 and total sample dry weight											
TC-WF-SurfGrabBed-			PES	SED-T	SE												
TC-WF-SubsurfGrabBed-			PES	SED-T	SE												
TC-EF-SurfGrabBed-			PES	SED-T	SE												
TC-EF-SubsurfGrabBed-			PES	SED-T	SE												
TC-LM-SurfGrabBed-			PES	SED-T	SE												
TC-LM-SubsurfGrabBed-			PES	SED-T	SE												
TC-401-SurfGrabBed-			PES	SED-T	SE												
TC-401-SubsurfGrabBed-			PES	SED-T	SE												
TC-Mouth-SurfGrabBed-			PES	SED-T	SE												
TC-Mouth-SubsurfGrabBed-			PES	SED-T	SE												

Comments/Special Instructions:

In addition to ASTM D422 we need the dry weight of each entire sample that we submit. Please call 206-407-9538 if you have any questions. Provide data in SPU EDD format.

Please follow the following size scale of bed material grain size (mm):

0.001, 0.002, 0.004, 0.008, 0.016, 0.031, 0.063, 0.125, 0.25, 0.5, 1.0, 2.0, 2.8, 4.0, 5.7, 8.0, 11.3, 16.0, 22.6, 32.0, 45.3, 64, 90.5, 128, 181, 256

Relinquished by (Name/CO/	Signature	Date/Time		Received By (Name/CO)	Signature	Date/Time
Relinquished by (Name/CO/	Signature	Date/Time		Received By (Name/CO)	Signature	Date/Time

Sample Type: PES= Primary Environmental Sample FSS- Field Split Sample **Method Type:** SED-T= sediment trap **Matrix Codes:** GW=Groundwater SE=Sediment SW=Surface Water W=Water (blanks) M=Material O=Other (specify)

Data Entry Review Worksheet

Project Name/No./Client: Taylor Creek/ 17-06530-005/ Seattle Public Utilities ________ Page ____ of ____

Data entered by: ________________ Data reviewed by: ________________

Laboratories: ________________ Date reviewed: ________________

Event ID ________ Sample Date ________________

Monitoring Stations: ________________________________

Parameters: ________________________________

____

Percentage of Data Reviewed:

Data Source (i.e., Lab or Field)	Monitoring Station	Parameter	Incorrect Value	Correct Value	Corrective Action

Notes:

Data Quality Assurance Worksheet

By ______________________

Project Name/No./Client: Taylor Creek / 17-06530-005/ Seattle Public Utilities

Date ____________ Page ___ of ___

Laboratory/Parameters: Analytical Resources, Inc. / SSC

Checked: initials ____________

Sample Date/Sample ID: ______________________

date ____________

Parameter	Completeness/ Methodology	Pre-preservation Holding Times (days)		Total Holding Times (days)		Method Blanks Reporting Limit	Matrix Spikes/ Surrogate Recovery (%)		Lab Control Samples Recovery (%)		Lab Duplicates RPD (%)		Field Duplicates RPD (%)		Instrument Calibration/ Performance	ACTION
		Reported	Goal	Reported	Goal		Reported	Goal	Reported	Goal	Reported	Goal[1]	Reported	Goal[1]		
SSC			**[illegible]7**		**[illegible]7**	[illegible] 1.0 0.1 0.05		**[illegible]**		**NA**		**[illegible] 25**		**[illegible] 25**		

[1] If the sample or duplicate value is less than five times the reporting limit, the difference is calculated rather than the relative percent difference (RPD). The QA goal is a difference < 2 times the detection limit instead of the number indicated in the goal column.

NA – not applicable or not available