Stormwater Action Monitoring
Effectiveness Studies

Quality Assurance Project Plan
Pilot Study for Non-proprietary Dissolved Metals Treatment: Oyster Shell Retrofits in Catch Basins

March 2019

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Quality Assurance Project Plan
Pilot Study to Assess Non-proprietary Dissolved Metals Treatment: Oyster Shell Retrofits in Catch Basins

Prepared for:
Washington State Department of Ecology
Stormwater Action Monitoring Effectiveness Studies

Submitted by:
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Citation


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QAPP Pilot Study to Assess Non-proprietary Dissolved Metals Treatment: Oyster Shell Retrofits in Catch Basins

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Certification
I certify under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering information, the information submitted is, to the best of my knowledge and belief, true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for willful violations.

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EXECUTIVE SUMMARY

Identifying retrofit options to fit particular stormwater treatment needs can be difficult, and non-proprietary options are limited for some common situations. Areas to be retrofitted are generally already built out and above-ground space may be limited. Additionally, typical dissolved metals concentrations in stormwater are often within a range that is difficult to reduce through common treatment methods, such as bioretention. Permittees are looking to decrease Water Quality Standards (WQS) exceedances due to low hardness combined with relatively low dissolved metals concentrations. Resources are also limited, and retrofit options with low installation and maintenance costs could increase the feasibility of more widespread stormwater treatment. Filtration of stormwater through oyster shells has been shown to reduce dissolved copper and zinc concentrations, while increasing hardness; thereby reducing toxicity of the copper and zinc remaining in the stormwater. The purpose of this study is to evaluate the effectiveness of oyster shell retrofits in stormwater catch basins for dissolved metals treatment and determine whether this non-proprietary technology should be evaluated through the Technology Assessment Protocol – Ecology (TAPE) program (Ecology 2011) in the future.

This two-year study (2019–2020) will utilize auto-samplers to collect composite stormwater samples during 10 storm events at catch basins within Basin 10 in the City of Mercer Island’s town center. Stormwater quality at this location has been monitored for the last six years, and dissolved copper and zinc concentrations have frequently exceeded WQS, partially driven by the low hardness levels typically present in stormwater. Four catch basins at this site have been retrofitted with baffles to allow for collection of discrete influent and effluent samples. The catch basins are distributed across two sub-basins as up- and downstream pairs, where oyster shells will be added to the two downstream “treatment” catch basins while the other two catch basins will be “untreated”. Pollutant concentrations will be analyzed in both influent and effluent samples from the “treated” and “untreated” catch basins to determine if pollutant levels are reduced by addition of the oyster shells.
1.0 PROJECT OVERVIEW

The purpose of this study is to evaluate the effectiveness of oyster shell retrofits in stormwater catch basins to increase hardness and decrease dissolved metal concentrations and to determine whether this non-proprietary technology should be evaluated through the Technology Assessment Protocol – Ecology (TAPE) program (Ecology 2011) in the future.

1.1 Problem Description, Prior Studies and Regulatory Requirements

It is well known that dissolved metals typically present in urban stormwater can be toxic to fish and other aquatic life, even at relatively low concentrations (Hansen et al. 1999, Sandahl et al. 2007, Tierney et al. 2010, De Schamphelaere et al. 2004). The toxicity of some metals, such as copper and zinc, is increased when water hardness levels are low. To account for the influence of hardness on aquatic toxicity, the Washington State Water Quality Standards (WQS) for copper and zinc are based on site-specific hardness levels. It is well established that stormwater can be a major source of copper and zinc to local lakes and streams, and hardness levels in stormwater are often very low (< 25 mg CaCO₃/L) (Hobbs et al. 2015). This results in copper and zinc concentrations in stormwater that are frequently above the acute and chronic WQS across the Puget Sound region (Hobbs et al. 2015). These conditions can have detrimental impacts on resident aquatic organisms in streams and lakes that receive substantial stormwater inputs.

Stormwater managers from municipalities with National Pollutant Discharge Elimination System (NPDES) Phase I Municipal Stormwater Permits are required to implement structural stormwater controls to reduce or prevent impacts to waters of the state (Section 5). There are several challenges to accomplish this in areas of existing site development: (1) there may be limited above-ground space for new treatment installations, (2) installation costs and time requirements for new treatments can be substantial, (3) maintenance requirements for new treatments can be extensive, and (4) many common filtration treatments, including bioretention, are not consistently effective at reducing dissolved copper concentrations to levels below those shown to cause toxicity (Clark 2000, Johnson et al. 2003, Clark et al. 2005, Taylor Associates, Inc. 2008, and Herrera 2014). Identifying a dissolved metals treatment retrofit option that addresses these challenges and is relatively inexpensive to maintain could expand the retrofit options for permittees looking to decrease WQS exceedances and reduce impacts to waters of Washington State.

Adding oyster shells to catch basins is a retrofit option that may satisfy these goals. Oyster and mussel shells are known to increase hardness due to the calcium content of their shells. A number of studies have demonstrated that copper, zinc, and phosphorus are readily bound to the shells over a variety of influent concentrations (Taylor Associates, Inc. 2008, Craggs et al. 2010, Landau Associates 2013, Dewell 2018); however, field studies have been limited. The mechanism of metals removal by oyster shells is likely due to adsorption and ion exchange (Craggs et al. 2010 and Landau Associates 2013). In addition to metals removal, the planned retrofit design (originally used by the Port of Seattle, Appendix A),
which causes the stormwater to move through the oyster shells and a baffle, likely increases the settling of particulates from stormwater. Reduction of particulate material in the effluent likely enhances removal of particulate-bound metals and other pollutants (e.g., bacteria and organic chemicals). Furthermore, this retrofit design requires minimal construction, with no impacts to above-ground areas. When used by the Port of Seattle, maintenance requirements for this type of retrofit were generally low; oyster shells were vectored from the catch basins and replaced yearly at relatively low cost (Silcox 2016).

Monitoring of the oyster shell retrofits by the Port of Seattle included grab samples collected about once a quarter from August 2010 to September 2011. For the first year, total zinc and copper were consistently reduced by about 60% to 90% over a range of influent concentrations, but effectiveness dropped sharply after about one year.

The limited chemistry data from these studies looks promising, but there has not been a robust monitoring effort to evaluate oyster shell retrofits. This project will collect influent and effluent samples from catch basins with and without oyster shell retrofits. Samples will be analyzed for conventional parameters, nutrients, and metals. Reductions in pollutant loads will be compared between the “treated” and “untreated” catch basins.

If stormwater effluent discharged from oyster shell retrofits is shown to consistently meet the dissolved metals treatment requirements, the next step could be to begin the process of including the treatment in the TAPE program. Once included in the TAPE program, municipal stormwater permittees would be able to add this non-proprietary technology to their stormwater design manuals.

### 1.2 Study Objectives

The study objectives are to:

- Collect time-weighted composite stormwater samples at the inlet and outlet of four catch basins (with and without oyster shell retrofits) for 10 discrete storms over two wet seasons. Samples will be analyzed for: total and dissolved metals, total suspended solids (TSS), total organic carbon (TOC), dissolved organic carbon (DOC), total and dissolved phosphorus, total nitrogen, hardness, pH, and flow.
- Calculate changes in concentrations between influent and effluent samples for each catch basin and each storm.
- Evaluate effectiveness of oyster shell retrofits in terms of dissolved metals treatment and phosphorus treatment as defined by the TAPE performance goals using the data collected from this pilot effort.
- Compare “treated” catch basin effluent dissolved metals concentrations to freshwater quality standards.
- Evaluate whether “treated” catch basins reduce the analyzed stormwater pollutants more than “untreated” catch basins.
- Communicate results with interested parties, including municipal stormwater permittees.
1.3 Study Location

The study will be located within Basin 10 in the City of Mercer Island’s town center. Stormwater at this location has been monitored for copper, zinc, bacteria, and conventional parameters for the last six years (King County 2016). This basin is a great location to evaluate effectiveness of oyster shell retrofits because copper and zinc concentrations have frequently exceeded WQS, partially driven by low hardness in stormwater. Additionally, during the latest stormwater sampling in this basin (2015-2016), dissolved copper and zinc concentrations were mostly within the influent concentration range required for testing under the TAPE program. This indicates effectiveness results could be representative of how well the retrofit would perform under testing for TAPE. Influent and effluent samples will be collected from four catch basins. This includes two sub-basins, each with one “treated” catch basin and one “untreated” catch basin directly upstream (Figure 1, Appendix A).

1.4 Tasks and Project Schedule

The tasks, schedule, and timeline required to successfully complete the project objectives are listed in Table 1. The sampling and analysis schedule is dependent on the timing of suitable storms; therefore, the proposed schedule is subject to change. The catch basins will be retrofitted with oyster shells under an agreement between the City of Mercer Island and King County prior to initiation of this monitoring study.

Table 1. Tasks and Project Schedule

<table>
<thead>
<tr>
<th>Activity</th>
<th>Date of Initiation</th>
<th>Deliverables</th>
<th>Final Deliverable Target Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>TASK 1.0 – Project Management</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Project management</td>
<td>Aug 31, 2018</td>
<td>Semi-annual progress reports</td>
<td>April 1, 2022</td>
</tr>
<tr>
<td>TASK 2.0 – Planning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality Assurance Project Plan (QAPP); Equipment purchases</td>
<td>Sept 2018</td>
<td>QAPP</td>
<td>Mar 2019</td>
</tr>
<tr>
<td>TASK 3.0 Field Sampling and Analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auto-samplers and flow meters installed and monitoring for 10 storm events over two wet seasons; Laboratory analysis</td>
<td>Mar 2019</td>
<td>Analytical data and flow data included in semi-annual progress reports</td>
<td>Sept 2020</td>
</tr>
<tr>
<td>TASK 4.0 – Final Report</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First season data validation</td>
<td>July 2019</td>
<td>Draft data validation memorandum</td>
<td>Nov 2019</td>
</tr>
<tr>
<td>Second season data validation and report outline</td>
<td>July 2020</td>
<td>Draft data validation memorandum and report outline</td>
<td>Jan 2021</td>
</tr>
</tbody>
</table>
1.5 Sampling Considerations and Constraints

This section describes conditions that may impact the project schedule, budget, or scope and the steps that will be taken to reduce the impact of these conditions.

1.5.1 Storm Event Considerations

The objective is to collect samples that will allow for the best measure of effectiveness of oyster shell retrofits to remove pollutants in catch basins. This will include samples from a variety of representative storm events. Ideally the study design would include collection of paired samples, in which the same “plug” of water is sampled as it flows into and out of a given catch basin. Sample collection would also ideally be paced so that similar plugs of water are collected at the upstream “untreated” locations during the same storm. This type of design would be advantageous because collecting samples from all locations during a given storm would better control for the variability associated with comparing data from different storms.

Preliminary analysis of flow data collected in Basin 10 in 2015-2016 suggests the system is flashy and collecting samples that represent this ideal sampling strategy may be challenging for all locations during each storm. See Sections 4.2 and 5.7.1 for storm event criteria and qualifying samples.

The project is subject to the timing of suitable storms and, therefore, the schedule is subject to change. If the target number of storm events is not reached by the end of the first wet season, additional storms events will be sampled the following year to achieve the targeted total number of storms (i.e., 10 events). Personnel affected by this change of schedule will be notified as soon as any changes are known.

1.5.2 Preventing Vandalism

Sampling equipment will be installed and left in place once the project is initiated. Sample equipment will be secured on-site in locked sheds anchored to metal tree planter cages or
concrete sidewalks to protect equipment from possible vandalism. Sheds will be covered with vinyl wrap that includes outreach and educations information on all four sides.
Figure 1. “Treated” and “Untreated” Catchbasins in the City of Mercer Island Town Center.
2.0 ORGANIZATION AND SCHEDULE

The project team consists of personnel from King County’s Water and Land Resources Division (WLRD), partners from the City of Mercer Island, and a stormwater action monitoring (SAM) coordinator from Ecology. Team members listed below with an asterisk by their name will be in regular contact to coordinate the sampling and analysis effort, and ensure adherence with the plan described in this Quality Assurance Project Plan (QAPP).

**King County WLRD, Science Section**
- Carly Greyell – Project Manager*
- Debra Bouchard – Technical Assistance
- Deborah Lester – Toxicology and Contaminant Assessment Unit (TCA) Supervisor

*This group is responsible for project planning, communicating between involved parties, and validating, synthesizing, and communicating results.*

**King County WLRD, KCEL**
- Katherine Bourbonais – Laboratory Project Manager (LPM)*
- Colin Elliott – Quality Assurance Officer
  - Analytical Group
  - Kevin Cummings – Metals Laboratory Supervisor
  - Brian Prosch – Conventionals Laboratory Supervisor
  - Field Science Unit (FSU)
  - Ben Budka – FSU Supervisor
  - Houston Flores – Lead Field Scientist*

*This group is responsible for all field work, analyzing samples for all parameters, KCEL data management and data review.*

**City of Mercer Island, Public Works**
- Patrick Yamashita, City Engineer

*This group is responsible for providing logistical support for field sampling and site-specific technical expertise.*

**SAM Representatives**
- Keunyea Song, Ecology – SAM Project Manager *

*This group is responsible for providing coordination between the Stormwater Workgroup (SWG) and the rest of the project team, as well as technical oversight.*

Table 2 lists the contact information for all project team members.
<table>
<thead>
<tr>
<th>Organization</th>
<th>Name</th>
<th>Contact Information</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td></td>
<td>Colin Elliott</td>
<td>206-477-7113; <a href="mailto:colin.elliott@kingcounty.gov">colin.elliott@kingcounty.gov</a></td>
</tr>
<tr>
<td></td>
<td>Kevin Cummings</td>
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<td>Brian Prosch</td>
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<td>Houston Flores</td>
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</tr>
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<td>Patrick Yamashita</td>
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</tr>
<tr>
<td>Ecology</td>
<td>Keunyea Song</td>
<td>360-407-6158; <a href="mailto:keunyea.song@ecy.wa.gov">keunyea.song@ecy.wa.gov</a></td>
</tr>
</tbody>
</table>
3.0 QUALITY OBJECTIVES

The data quality objectives (DQOs) for this effort are to collect data of known and sufficient quality to meet study goals. The data quality indicators of precision, bias, sensitivity and accuracy are described within this section, while representativeness, comparability, completeness are described in Section 4, after the description of the sampling design. Detailed descriptions and specific limits for quality assurance/quality control (QA/QC) samples are discussed in Section 7.

3.1 Precision

Precision is the agreement of a set of results among themselves and is a measure of the ability to reproduce a result. For this project, evaluation of precision will be based on laboratory replicates and matrix spike duplicates. Field replicates will be collected as additional volume from a single composite sample collected by autosampler due to space limitations for extra equipment at the sampling sites. Differences between results for these quality assurance/quality control (QA/QC) samples must be within the criteria presented in Section 7 to meet measurement quality objectives (MQOs).

3.2 Bias

Bias is a measure of the difference due to a systematic factor, between an analytical result and the true value of an analyte. Bias will be evaluated by analyzing field blanks (Section 5.9), method blanks, spike blanks, matrix spikes, certified reference materials, laboratory control samples and/or surrogates, along with ongoing recovery sample control charts. Results for these QA/QC samples must be within the criteria presented in Section 7 to meet MQOs.

3.3 Sensitivity

Sensitivity is a measure of the capability of analytical methods to meet the study goal. The analytical method detection limits (MDLs) presented in Section 7 are expected to be sensitive enough to detect the study parameters at these sites, with the potential exception of dissolved cadmium, lead, and phosphorus. Study goals can still be achieved, as these parameters are not the primary focus of the study.

3.4 Accuracy

Accuracy is an estimate of the difference between the true value and the measured value. The accuracy of a result is affected by both systematic and random errors. Accuracy of the results will be analyzed using field blanks (Section 5.9), method blanks, matrix spikes, certified reference materials and/or laboratory control samples, along with ongoing recovery sample control charts. Results for these QA/QC samples must be within the criteria presented in Section 7 to meet MQOs.
4.0 SAMPLING DESIGN

The goal of this study is to evaluate the effectiveness of oyster shell retrofits to improve stormwater quality on an individual catch basin level. The following sections describe the sampling design to achieve this study goal.

4.1 Sampling Locations and Frequency

The four catch basin sampling locations for this project are located in Basin 10 in the City of Mercer Island’s town center (Figure 1 and Table 3). Basin 10 drains the majority of the City of Mercer Island’s business district, as well as single-family and high-density residential neighborhoods. The two “treated” catch basins in this study (10-108 and 10-647) were part of previous stormwater quality and continuous flow monitoring efforts in 2013-2016. These two drainage basins connect with the stormwater gravity main trunk line within the town center intersection of SE 27th Street and 77th Ave SE. As discussed in earlier reports (King County 2011, 2013, 2015, and 2016), water quality concerns in Basin 10 include dissolved copper and zinc concentrations that exceed the WQS. Each site will be sampled during each of ten storms from January 2019 to June 2020.

<table>
<thead>
<tr>
<th>Inflow Locator ID</th>
<th>Description</th>
<th>Outflow Locator ID</th>
<th>Description</th>
<th>Latitude, Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-109-IN</td>
<td>Inflow to catch basin 10-109 (untreated - control)</td>
<td>10-109-OUT</td>
<td>Outflow from catch basin 10-109 (untreated - control)</td>
<td>47.586789, -122.235860</td>
</tr>
<tr>
<td>10-108-IN</td>
<td>Inflow to catch basin 10-108 (untreated - collected before entering oyster shells)</td>
<td>10-108-OUT</td>
<td>Outflow from catch basin 10-108 (treated – collected after exposure to oyster shells)</td>
<td>47.586786, -122.235252</td>
</tr>
<tr>
<td>10-365-IN</td>
<td>Inflow to catch basin 10-365 (untreated - control)</td>
<td>10-365-OUT</td>
<td>Outflow from catch basin 10-635 (untreated - control)</td>
<td>47.586779, -122.234402</td>
</tr>
<tr>
<td>10-647-IN</td>
<td>Inflow to catch basin 10-647 (untreated - collected before entering oyster shells)</td>
<td>10-647-OUT</td>
<td>Outflow from catch basin 10-647 (treated – collected after exposure to oyster shells)</td>
<td>47.586789, -122.234883</td>
</tr>
</tbody>
</table>

4.2 Qualifying Storm Event Criteria for Sampling

One challenging aspect of stormwater sampling is storm variability. The use of storm criteria increases the chances that sampling equipment is only deployed when stormwater flows will result in sufficient sample volume. The criteria presented below have been adopted from the TAPE Guidance for Evaluating Emerging Stormwater Treatment Technologies (Ecology 2011).

Storm Event Guidelines:

- Rainfall during storm event: at least 0.15 inches, no fixed maximum
- Rainfall duration: at least one hour, no fixed maximum
• Antecedent dry period: at least six hours with less than 0.04 inches of rain
• Flow requirements: Effluent must be flowing out of catch basins

### 4.3 Measured Parameters

Each stormwater sample will be analyzed for the following parameters:

- Cadmium (dissolved, total)
- Copper (dissolved, total)
- Lead (dissolved, total)
- Zinc (dissolved, total)
- TSS
- TOC
- DOC
- Orthophosphate phosphorus
- Total phosphorus
- Total nitrogen
- pH
- Hardness
- Field measurements (Section 5.3)

### 4.4 Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at the sampling point, or an environmental condition. Collecting composite samples with an autosampler allows for a representative characterization of average concentrations over a storm event; however, the trade-off is that the 15-minute holding times for dissolved metals and orthophosphate phosphorus samples to be filtered will not be met. pH tested in the lab will also exceed the 15-minute holding time for analysis. Samples will be collected in a manner that minimizes potential contamination and other types of degradation in the chemical and physical composition of the water. This will be achieved by following guidelines described in Section 5 for sampler decontamination, sample acceptability criteria, sample processing, observing proper holding times (with the exception listed above), preservation, and storage of samples. In order to reduce the risk of cross-contamination between sampling locations, all tubing (sampling and sample splitting tubing) will be pre-cleaned and either new or dedicated to a particular site, as described in Section 5. In order to better estimate average conditions in the stormwater system, a range of storm intensities will be targeted. However, adequate sample volume is important, thus the study may not represent very small storm conditions that do not generate enough flow for sampling.

### 4.5 Comparability

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared to another. Comparability is addressed through use of standard techniques to collect and analyze representative samples, along with standardized data verification and reporting procedures described in this QAPP. Changes or updates to analytical methods and sampling techniques midway into the project must be approved by the project managers and QA signatories before being implemented.
The purpose of this study is to provide regional stormwater permittees with useful information about the effectiveness of oyster shell retrofits in catch basins to reduce dissolved copper and zinc concentrations, (with accompanying increases in hardness). Although the retrofit designs for this project are unique due to site considerations, this project will gain quantified information that can be compared to previous studies on the use of oyster shells for the collective performance on stormwater quality.

Historical monitoring data may be used for comparison with stormwater chemistry data collected by this project. Aspects to consider for comparability are the data quality and measurement quality objectives of the prior study such as: sampling method, analytical method, storm conditions sampled, and location. While the two “treated” catch basin locations were previously included in the stormwater monitoring done for the City of Mercer Island, the samples were collected as discrete grabs. The samples collected for this study will be time weighted composites collected using autosamplers over a period of multiple hours. Grab samples from the prior study are anticipated to be within the ranges for concentrations gathered for this study.

Drainage areas are similar between each catch basin pair, but flow will be monitored at all catch basins to assess comparability between “treated” and “untreated” catch basins. Additionally, influent concentrations are expected to be similar between “treated” and “untreated” catch basins, but substantial differences could affect comparability.

4.6 Completeness

Completeness is defined as the total number of samples analyzed for which acceptable analytical data are generated, compared to the total number of samples submitted for analysis. Sampling according to storm criteria, along with adherence to standardized sampling and testing protocols outlined in this QAPP, will aid in providing a complete set of data for this project. The goal for completeness is a minimum of eight storm events (goal of ten storms) sampled at each location over a two-year period. The target number of storms is based on time and resource limitations and not on a statistical power analysis. The samples from each event should produce greater than 90% acceptable chemical data under the QC conditions described in Section 7 of this QAPP. However, all dissolved metals and orthophosphate phosphorus analyses will be “H” flagged because samples will be filtered in the lab and exceed the requirement for filtration within 15-minutes of sample collection (see Section 5.7). pH tested in the lab will also exceed the 15-minute holding time for analysis and will be “H” flagged.

Storms are unpredictable, and while preliminary flow monitoring and implementation of storm criteria increase the chances of collecting adequate sample volume, it is still possible that sampling will result in insufficient volume to perform all analyses. Therefore, samples will be analyzed when there is sufficient volume to analyze at a minimum metals and conventional parameters in each composite samples at both the inlet and outlet of a catch basin pair (‘treated” catch basin and upstream “untreated” catch basin). If the volume of any influent or effluent samples at a given catch basin pair is less than two liters, none of the samples will be analyzed. The target is that 90% of the samples will have sufficient
volume to analyze all parameters, including laboratory QC samples, which require 2.6 liters. Table 7 in Section 6 lists the parameters in order of priority. If completeness goals are not achieved, the project team will evaluate if the DQOs can still be met or if additional samples must be collected.
5.0 SAMPLING AND MONITORING PROCEDURES

Sample collection and monitoring procedures are presented here. The following sections also describe additional sampling considerations, equipment, sampling initiation, sample handling, decontamination procedures, collection of QA/QC samples, and preventative maintenance.

5.1 Continuous Flow Measurements

Continuous flow data will be collected at each “treated” catch basin using an air bubbler (level sensor-type flow meter; ISCO® 730 Bubbler Flow Module). Flow at the “treated” catch basins should be comparable to flow at the upstream “untreated” catch basins due to similar sizes of the contributing basins. Continuous flow data will be analyzed for several storm events prior to sampler deployment to gain a better understanding of flow in the basin. Rainfall data from nearby King County rain gages and this flow data will provide information necessary to program the autosamplers based on forecasted rainfall.

Equipment installation includes, but is not limited to:

- Installation of sampler tubing in stormwater pipe
- Installation of mounting rings for sampler tubing and flow meter probe
- Installation of a liquid level actuator or telemetry equipment
- Installation of other necessary sampler equipment into/onto sampler (bottles, flow meter)

Installation and monitoring procedures will follow SOP NPDES-CM-1000 (King County 2008; see Section 2.1.4) and the guidelines in the instrument manuals (Teledyne 1995). The bubbler will determine the level in each pipe, and the ISCO 6712 sampler will convert that level into flow rate.

During equipment installation, the flow meter will be programmed and tested. If there is no flow in the facility to allow for a test run at the time of installation, field staff will return when flow is present to ensure that the equipment is working properly.

5.2 Composite Sample Collection

Composite stormwater samples will be collected using ISCO 6712 autosamplers (Table 4). Autosamplers will be equipped with 20-liter glass (or suitable fluorinated plastic) sample carboys. The carboys will be dedicated to specific sampling stations for the duration of the project. Autosamplers will be installed inside protective sheds at ground level. The peristaltic pump in the autosamplers will be fitted with new silicon tubing at the beginning of the study. Tubing will remain site-dedicated for each sampling event. All tubing, new and
site-dedicated, should be decontaminated prior to use for this project. Site-dedicated Teflon® tubing and stainless steel fittings shall be used for all other tubing.

Influent sample lines will be positioned towards the center of the horizontal cross-section of the catch basin at the height of the base of the inflow pipe. The goal of this sampling position is to collect a representative mix of stormwater entering from the inflow pipe and the grate above (before contact with oyster shells in the “treated” catch basins). The effluent sample line will be positioned behind the baffle at the height of the outflow pipe to capture stormwater that has passed through the catch basin (after contact with oyster shells in the “treated” catch basin). See Appendix A for diagram.

Sampling will be enabled when the depth of the water in the outlet pipe reaches a pre-determined level as measured by the autosampler connected to the ISCO 730 Bubbler Module. This autosampler will then send an ‘enable’ SMS message to the three upstream autosamplers. Based on a pre-determined time interval, a pulse trigger is sent to the autosampler to collect a pre-determined sample aliquot ranging in volume from 100-mL to 500-mL over a six to 24 hour period. The aliquot volume and timing will be based on anticipated flow conditions predicted using various online rain forecasts (primarily www.forecast.weather.gov, www.atmos.washington.edu and www.wunderground.com), as well as previous flow and rainfall monitoring data with a goal of collecting a total of three liters over at least 75% of the hydrograph. If the storm water stops flowing before the program has finished, an alarm will be sent out and the program will be remotely disabled. The end of the composite period will be considered the start of the holding time period for all samples.

Sampling personnel will retrieve samples as soon as possible after the sampling event ends. Once on site, field personnel will review flow data to confirm that stormwater runoff has subsided or that sampling occurred for a maximum of 24 hours. If the target volume has not been reached at less than 24 hours, and storm flow is still present, the sampling program will continue. Sampling will be complete once the target volume has been reached, stormwater runoff has ceased, or the sampler has sampled for 24 hours.

Samples will then be placed on ice and transported to the KCEL. Upon arrival at the KCEL, samples will be split into the necessary aliquots and appropriate containers. Samples requiring filtration will be processed as soon as possible with a 0.45 micron capsule filter for dissolved metals and a 0.45 micron surfactant-free cellulose acetate (SFCA) syringe filter for dissolved phosphorus (orthophosphate) and DOC. All parameters requiring filtration within 15 minutes of sample collection will be flagged with an “H” qualifier. pH tested in the lab will also exceed the 15-minute holding time for analysis and will be “H” flagged.

1 The target sampling duration may be modified after initial flow monitoring.
5.3 Field Measurements

Field measurements will be collected prior to sampling and during sample retrieval when logistically feasible. Field measurements will not be collected if there is not active flow through the catch basins. Field measurements will provide information about the characteristics of each storm for data interpretation and will include the following:

- Dissolved oxygen, temperature, pH and conductivity measured with an EXO YSI Sonde directly in each of the four catch basins where the influent samples are collected,
- Sediment accumulation in the two “untreated” catch basins measured as an average of the depth from the street surface to the top of sediment in the sump at three points within the catch basin,
- Depth of oyster shells in the two “treated” catch basins measured as an average of the depth from the street surface to the top of the oyster shells in the sump at three points within the catch basin (to determine if shells are compacting or exiting the catch basin over time).

Table 4 summarizes the sampling strategy for the “treated” catch basins and the upstream “untreated” catch basins.

Table 4. Sampling Strategy for the “Treated” and “Untreated” Catch Basins

<table>
<thead>
<tr>
<th>Parameter Group</th>
<th>Samples per Storm</th>
<th>Target Number of Storms</th>
<th>Max Number of Samples</th>
<th>Text Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS, pH, Nutrients, Metals, TOC, DOC, Hardness</td>
<td>8</td>
<td>8-10</td>
<td>80</td>
<td>Composite sample for both influent and effluent of two “treated” and two “untreated” catch basins.</td>
</tr>
<tr>
<td>Field measurements</td>
<td>8</td>
<td>8-10</td>
<td>80</td>
<td>Dissolved oxygen, temperature, pH, conductivity, and depth of sediment accumulation or oyster shells in “untreated” and “treated” catch basins, respectively. Measured twice per storm: once prior to sample collection (during field visit for sampling initiation) and once during sample retrieval (when logistically feasible as described above).</td>
</tr>
</tbody>
</table>

2 Sampling can be triggered remotely and field personnel may not be present on site in order to take measurements during the storm event.
3 pH will also be analyzed in the laboratory as it may be particularly influential in treatment effectiveness.
4 If the baffle design allows it, measurements will also be taken from behind the baffle.
5 If the baffle design allows it, measurements will also be taken from behind the baffle.
5.4 Sampling Initiation

5.4.1 Monitoring Forecast

Although it would be ideal to randomize storm sampling days, this is unrealistic for the personnel resources. Alternatively, the King County project manager and field team will plan sampling events around the weather forecast and available personnel. When a qualifying storm is forecast (as defined in Section 4.2), field personnel will communicate with the project manager to discuss preparation for the upcoming event. The weather forecast will be used to program the autosamplers based on the predicted rainfall amount.

5.4.2 Sampling Initiation Procedures

Once a decision has been made to initiate sampling, the field team will gather the necessary equipment for deployment (including decontaminated containers, and ice) and proceed to the sampling sites. When collecting or handling sample containers, field personnel will wear powder-free nitrile gloves for safe handling to prevent cross contamination of samples.

The field team will prepare autosamplers prior to the sampling event. This may include decontamination of autosampler tubing, placement of sample container(s) in the sampler, and programming each site’s autosampler based on weather forecast information.

5.5 Sampling Considerations

The field team will need to be vigilant of the roadway during sample collection and consider blocking the right-of-way with traffic cones to provide a more protected workspace. Despite the proximity to the street, sample collection should be possible without entering the roadway; therefore, traffic control is not required.

Flow meter installation (and sampler trouble shooting) may require entering confined spaces. Any confined space entry will be done by King County personnel who have the training and experience to safely enter these spaces. King County confined space entry requirements and safety protocols will be followed at all times. Field personnel are confined space entry certified through the Wastewater Treatment Division (WTD) Permit-Required Confined Space Entry Program. All guidelines and requirements for confined space entry can be found in the WTD Permit-Required Confined Space Entry Program Manual (King County 1998).

5.6 Additional Sampling Equipment

Sampling and safety supplies include the following:

- Ziploc® bags
- Cooler with ice
- Nitrile gloves
• Field notebook
• Sample labels
• Chain-of-custody forms
• Camera
• Safety vests
• Safety shoes
• Appropriate traffic control equipment

When visiting the sampling site, field personnel will record the following information on field forms that are maintained in a waterproof field notebook:

• Date and time of sample collection/visit
• Name(s) of sampling personnel
• Weather conditions
• Number and type of samples collected
• Instrument calibration procedures
• Field measurements
• Sequence of events (order of sites sampled)
• Time of flow data download
• Log of photographs taken
6
• Comments on the working condition of the sampling equipment
• Deviations from sampling procedures
• Unusual conditions (e.g., water color or turbidity, presence of oil sheen, odors, and land disturbances)
• Signature of field project manager

5.7 Sample Handling Procedures

5.7.1 Qualifying Samples – Post-Sampling

Actual weather events will not always match the forecasted weather. As such, following sample collection, but prior to sample analysis, a determination will be made to ensure the storm event met criteria. After sample collection, the project manager and field personnel will work together to analyze flow and rainfall data to evaluate hydrograph conditions during the sampled storm event. The storm sample is considered representative if the event meets criteria listed in Section 4.2 and the hydrograph shows that 75% of the sample

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6 At a minimum, photos must document the autosampler and flow meter setup. Any deviations from the QAPP or unusual conditions must also be photographed.
volume was collected during storm flows\(^7\). If the storm meets the acceptance criteria, the sample volume of the paired samples will be evaluated to determine if target volumes are adequate (3 L for each influent and effluent sample at a given catch basin pair). If this criteria results in a number of missed attempts, it may be reexamined and altered by the project team to be less restrictive. The decision to analyze samples must be made within 24 hours of sample collection in order to comply with sample holding times.

### 5.7.2 Sample Delivery and Storage

After sampling is complete, all samples will be stored on ice and transported back to KCEL. Each sample will then be split into individual, analyte-specific laboratory containers. Sample splitting will be done by continuously agitating the sample in the carboy while transferring sample aliquots to the appropriate laboratory containers using a pre-cleaned, site-dedicated Teflon® siphon tube. Only new, pre-cleaned silicon tubing will be used in this process. Each sample container will be filled to the appropriate level from the carboy. This procedure will ensure a representative sample from the carboy in each laboratory sample container.

Once the samples have been split, the orthophosphate phosphorus samples will be filtered using a 0.45 micron SFCA syringe filter. Dissolved metals samples collected by autosamplers will also be filtered using a cleaned Nalgene 500-mL filtration apparatus with a 0.45 micron filter and a peristaltic pump. As previously discussed, these samples will be filtered outside the 15-minute holding time requirements and the resulting data will be qualified with an “H” flag and a Data Anomaly Form (DAF) will be written explaining the “H” flag.

Table 5 shows sample handling and storage requirements for all parameters, in order of priority.

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\(^7\) A storm flow threshold will be determined through preliminary flow monitoring, and will represent a flow rate indicative of storm conditions.
### Table 5. Prioritized Parameter List with Sample Volume, Container, Preservation, Storage, and Holding Time Requirements

<table>
<thead>
<tr>
<th>Analyte(s)</th>
<th>Container</th>
<th>Storage Prior to Preservation</th>
<th>Preservation Holding Time</th>
<th>Preservation Technique</th>
<th>Analysis Holding Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total metals and hardness</td>
<td>Acid washed 500-mL HDPE</td>
<td>transport on ice</td>
<td>Add acid ≥24 hours before digestion</td>
<td>Ultra-pure HNO₃ to pH &lt;2</td>
<td>180 days</td>
</tr>
<tr>
<td>Dissolved metals</td>
<td>Acid washed 500-mL HDPE or PS filter unit</td>
<td>transport on ice</td>
<td>15 minutes for field filtration, add acid ≥24 hours before analysisᵃ</td>
<td>Ultra-pure HNO₃ to pH &lt;2</td>
<td>180 days</td>
</tr>
<tr>
<td>Total suspended solids</td>
<td>1-L CWM HDPE</td>
<td>Cool to ≤6° C</td>
<td>NA</td>
<td>Cool to ≤6° C</td>
<td>7 days</td>
</tr>
<tr>
<td>Total organic carbon</td>
<td>125-mL amber glass</td>
<td>Cool to ≤6° C</td>
<td>1 day</td>
<td>Add H₃PO₄ to pH &lt; 2, Cool to ≤6° C</td>
<td>28 days</td>
</tr>
<tr>
<td>Dissolved organic carbon</td>
<td>125-mL AWM HDPE</td>
<td>Cool to ≤6° C</td>
<td>1 day</td>
<td>Filter, H₃PO₄ to pH &lt;2, Cool to ≤6° C</td>
<td>28 days</td>
</tr>
<tr>
<td>pH</td>
<td>500-mL CWM HPDE</td>
<td>Cool to ≤6° C</td>
<td>15 minutes</td>
<td>Cool to ≤6° C</td>
<td>15 minutes</td>
</tr>
<tr>
<td>Total nitrogen</td>
<td>250-mL CWM HDPE</td>
<td>Cool to ≤6° C</td>
<td>2 daysᵇ</td>
<td>Freeze at -20° C</td>
<td>28 days</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>Same container as Total Nitrogen</td>
<td>Cool to ≤6° C</td>
<td>2 daysᵇ</td>
<td>Freeze at -20° C</td>
<td>28 days</td>
</tr>
<tr>
<td>Orthophosphate Phosphorus</td>
<td>60 mL CWM HDPE</td>
<td>NA</td>
<td>15 minutesᵃ</td>
<td>Filter and freeze at -20° C</td>
<td>14 days</td>
</tr>
</tbody>
</table>

ᵃ Samples will not be filtered within holding time for this project and will be qualified with H flags during data validation.
ᵇ Samples and filtrates may be stored at ≤6° C if digested within 2 days of collection, otherwise they must be frozen. Holding time is then 28 days.

HDPE – high density polyethylene; HNO₃ – nitric acid; PS – polystyrene; NA – not applicable; CWM – clear wide mouth; ANM – amber narrow mouth; AWM – amber wide mouth; H₃PO₄ – phosphoric acid
5.7.3 Chain of Custody

Chain of custody (COC) will commence at the time that each autosampler is deployed. Autosamplers will be secured to ensure no tampering occurs. Thus, all samples will be under direct possession and control of King County field personnel. For COC purposes, closed/latched storm drains, autosamplers, and field vehicles will be considered “controlled areas.” All sample information will be recorded on a COC form, an example of which is included as Appendix B. This form will be completed in the field and will accompany all samples during transport and delivery to KCEL. Upon arrival at the KCEL, the samples will be split, preserved, and filtered as needed, then logged into Laboratory Information Management System (LIMS) and stored in a secure refrigerator. The date and time of sample delivery will be recorded and the COC form will be signed off in the appropriate sections at this time. Once completed, original COC forms will be archived in the project file.

Samples delivered after regular business hours will be split and preserved as needed and stored in a secure refrigerator until the next day.

5.7.4 Sample Documentation

Sampling information and sample metadata will be documented using the methods described below:

- Field sheets generated by LIMS will be used at all stations and will include the following information:
  1. Sample ID number
  2. Locator/station name
  3. Date and time of sample collection (start and end times of the compositing period)
  4. Depth to top of sediment or oyster shells, as appropriate
  5. Initials of all sampling personnel

- LIMS-generated container labels will identify each container with a unique sample number, station and site names, collect date, analyses required, and preservation method.

- The field sheet will contain records of collection times, general weather, and the names of field crew.

- COC documentation will consist of KCEL’s standard COC form, which is used to track release and receipt of each sample from collection to arrival at the lab.

- A Field Observation Form will be completed after each successful sampling event detailing the field observations from FSU staff. This document will be uploaded to LIMS.
5.8 Decontamination Procedures

Once samples are collected, all re-usable equipment will be decontaminated. Autosampler containers shall be cleaned with: (1) Alconox® or other suitable laboratory detergent; (2) a sulfuric acid rinse; and (3) a deionized water rinse. Tubing shall remain in place for the duration of the project due to the logistical challenges with removal and replacement.

All stainless steel fittings and connectors are to be cleaned in the same manner except they are not subject to the acid rinse step. Composite autosampler bottles and autosampler tubing will be cleaned prior to each sampling event according to laboratory standard operating procedures for collecting samples for low-level analysis using autosamplers (KCEL SOP #234 and KCEL SOP #223). Proper personal protective equipment (new powder-free gloves for each site) should be worn during sampling activities and during decontamination processes.

5.9 Collection of QA/QC Samples

Table 6 summarizes the QA/QC samples to be collected to satisfy project objectives.

<table>
<thead>
<tr>
<th>QA/QC Sample Type</th>
<th>Number of QA/QC Samples</th>
<th>Collection Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling equipment Blank</td>
<td>One for autosampler setup (1 total)</td>
<td>Run ASTM Type I or II de-ionized water through autosampler equipment after decontamination and collect sample in the appropriate containers with preservative for a full analysis of all parameters collected during a sampled storm event. Place immediately on ice.</td>
</tr>
<tr>
<td>Oyster shell rinsate blank</td>
<td>One at the beginning of each storm season (2 total)</td>
<td>Soak unused oyster shells in ASTM Type I or II de-ionized water for one hour, agitating shells lightly every 15 minutes. Collect a sample for total metals analysis in the appropriate container. Place immediately on ice.</td>
</tr>
<tr>
<td>Field Replicates</td>
<td>One for each storm event (8-10 total)</td>
<td>Collect additional volume at one sampling site for each storm event to fill extra bottles for replicate analysis of all parameters. Rotate across all sampling sites so that each site has at least one field replicate over the course of the project.</td>
</tr>
</tbody>
</table>

5.10 Periodic Preventative Maintenance

Periodic preventative maintenance of equipment will occur as needed between storm events to ensure equipment is operating properly. Signs of vandalism, rusting equipment, equipment failure, or other maintenance issues will be documented in field notebooks or on field data forms. Any significant changes in site conditions that will affect sampling will be documented in the final report under Deviations from the QAPP.
6.0 MEASUREMENT PROCEDURES

6.1 KCEL Analytical Methods and Detection Limits

Analytical methods are presented in this section, along with analyte-specific detection limit goals. For conventional parameters, nutrients, and metals, the terms MDL and RDL used in the following subsections refer to method detection limit and reporting detection limit, respectively. The KCEL reports both the LIMS reporting detection limit (LIMS RDL) and the LIMS method detection limit (LIMS MDL) for each sample and parameter, where applicable.

A practical quantitation limit (PQL) is generally defined as the minimum concentration of a chemical constituent that can be reliably quantified while the MDL is defined as the minimum concentration of a chemical constituent that can be detected. The LIMS RDL is analogous to the PQL for all analyses. It is verified either by including it on the calibration curve or by running a low level standard near the PQL value during the analytical run.

Actual LIMS MDLs and RDLs may differ from the target detection limit goals as a result of necessary analytical dilutions or a reduction of extracted sample amounts based on available sample volumes. When sample extracts are diluted because the concentrations for one or more target analytes exceeded the upper end of the calibration curve or parameter-specific interferences, MDLs and RDLs from the original, undiluted extract will be reported for parameters other than the target analytes that required dilution. Every effort will be made to meet the MDL/RDL goals listed in the QAPP; however, there may be times when the MDL/RDL values rise because the sample must be run at a greater dilution. This may be due to the concentration of some target analytes exceeding the calibration range, interfering target or non-target compounds, or run QC not passing (e.g., internal standard failures). Non-detected target analytes will be reported from the lowest dilution possible (no interferences and the run QC must pass). Target analytes that are detected must be reported from an appropriate dilution.

Tables 7 and 8 presents the methods and sensitivity for parameters analyzed in the laboratory and field. Shortage of sample volume or excessive interferences may increase the limit goals presented here.
Table 7. Method and Detection Limit Goals for Parameters Analyzed at the KCEL

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Analytical Method</th>
<th>Method Detection Limit</th>
<th>Reporting Detection Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved organic carbon</td>
<td>SM5310B</td>
<td>0.5 mg/L</td>
<td>1 mg/L</td>
</tr>
<tr>
<td>Total organic carbon</td>
<td>SM5310B</td>
<td>0.5 mg/L</td>
<td>1 mg/L</td>
</tr>
<tr>
<td>Total suspended solids</td>
<td>SM2540D</td>
<td>0.5 mg/L</td>
<td>1.0 mg/L</td>
</tr>
<tr>
<td>Orthophosphate Phosphorus</td>
<td>SM4500-P-F</td>
<td>0.0005 mg/L</td>
<td>0.002 mg/L</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>SM4500-P-B, F</td>
<td>0.005 mg/L</td>
<td>0.01 mg/L</td>
</tr>
<tr>
<td>Total nitrogen</td>
<td>SM4500-N-C</td>
<td>0.05 mg/L</td>
<td>0.1 mg/L</td>
</tr>
<tr>
<td>pH</td>
<td>SM4500-H-B</td>
<td>N/A (^{a})</td>
<td>N/A (^{a})</td>
</tr>
<tr>
<td>Hardness as CaCO(_3)</td>
<td>(EPA 200.7 or EPA 200.8) / SM2640B.ED19</td>
<td>200.7 = 0.25 mg CaCO(_3)/L</td>
<td>200.7 = 1.24 mg CaCO(_3)/L</td>
</tr>
<tr>
<td>Total cadmium</td>
<td>EPA 200.8</td>
<td>0.05 µg/L</td>
<td>0.25 µg/L</td>
</tr>
<tr>
<td>Dissolved cadmium</td>
<td>EPA 200.8</td>
<td>0.05 µg/L</td>
<td>0.25 µg/L</td>
</tr>
<tr>
<td>Total copper</td>
<td>EPA 200.8</td>
<td>0.2 µg/L</td>
<td>2.0 µg/L</td>
</tr>
<tr>
<td>Dissolved copper</td>
<td>EPA 200.8</td>
<td>0.2 µg/L</td>
<td>2.0 µg/L</td>
</tr>
<tr>
<td>Total lead</td>
<td>EPA 200.8</td>
<td>0.1 µg/L</td>
<td>0.5 µg/L</td>
</tr>
<tr>
<td>Dissolved lead</td>
<td>EPA 200.8</td>
<td>0.1 µg/L</td>
<td>0.5 µg/L</td>
</tr>
<tr>
<td>Total zinc</td>
<td>EPA 200.8</td>
<td>0.5 µg/L</td>
<td>2.5 µg/L</td>
</tr>
<tr>
<td>Dissolved zinc</td>
<td>EPA 200.8</td>
<td>0.5 µg/L</td>
<td>2.5 µg/L</td>
</tr>
</tbody>
</table>

\(^{a}\) Sensitivity of pH measurements is ±0.2 standard units.

Table 8. Method and Sensitivity for Parameters Analyzed in the Field

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Method (SOP)</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductivity</td>
<td>KCEL SOP #206v2</td>
<td>15 µmhos/cm</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>KCEL SOP #201v3</td>
<td>±0.2 mg/L</td>
</tr>
<tr>
<td>pH</td>
<td>KCEL SOP #202v3</td>
<td>±0.2 standard units</td>
</tr>
<tr>
<td>Temperature</td>
<td>KCEL SOP #203v3</td>
<td>±0.2 degrees Celsius</td>
</tr>
</tbody>
</table>
7.0 QUALITY CONTROL

This section describes the applicable field and laboratory QC required for this project. In general, QC measures include (1) ensuring that field and laboratory personnel are well trained and exhibit attention to detail, and (2) making certain that equipment calibrations are well documented and performed carefully and consistently following manufacturer’s instructions.

7.1 Flow Meter and Autosampler Operation

KCEL field staff will install, maintain and calibrate flow monitoring equipment according to the equipment manuals (Teledyne 1995). KCEL field staff will set up, program, and maintain the ISCO Autosamplers according to the equipment manual (Teledyne 2001). The following steps will also be taken as part of the QC process:

- Following initial set-up, field calibration checks will involve re-measuring water levels in the pipes at each station when flows are present (for at least three storms over the study period). The meter will be recalibrated as necessary, and the relative percent difference (RPD) between the recorded water levels should be within 10% or the generated flow data will be qualified according to Section 8.2. Results will be documented in the field sheets.
- Field staff will download flow data (at a minimum of every 30 days) and ensure flow meters are working properly.
- All data will be reviewed, rated for accuracy, and approved before being submitted as a final product.
- The Manning Equation is only to be used to calculate gravity flow; therefore, if the pipe fills, flow cannot be calculated accurately due to pressure influences. The data will be reviewed to verify the water level remained below the full diameter of the pipe. If the water level exceeds the diameter of the pipe, the project team will explore alternative methods of monitoring flow.
- Data management will follow procedures outlined in Section 8.0.

7.2 Laboratory Measurements

Descriptions of the required laboratory QC samples are listed below.

- Analysis of method blanks and filtration blanks is used to evaluate the concentration of contamination that might be associated with the processing and analysis of samples in the laboratory and introduce bias into the sample result. Method blank and filtration blank results for all target analytes should be “less than the MDL.”
- A laboratory duplicate is a second aliquot of a sample, processed concurrently and in an identical manner with the original sample. The laboratory duplicate is processed through the entire analytical procedure along with the original sample in the same quality control batch. Laboratory duplicate results are used to assess the precision.
of the analytical method and the RPD between the results should be within method-specified or performance-based QC limits.

- A laboratory control sample is a sample of known analyte concentration(s) that is prepared in the lab from a separate source of analyte(s) relative to the calibration standards. Since the laboratory control sample analysis should follow the entire analytical process, it should be stored and prepared following the same procedures as a field sample. Analysis of a laboratory control sample is used as an indicator of method accuracy and long-term analytical precision.

- A spike blank is a spiked aliquot of clean reference matrix used for the method blank. The spiked aliquot is processed through the entire analytical procedure. Analysis of the spike blank is used as an indicator of method accuracy. It may be conducted in lieu of a laboratory control sample. A spike blank duplicate should be analyzed whenever there is insufficient sample volume to include a sample duplicate or matrix spike duplicate in the batch.

- A matrix spike is a sample aliquot fortified with a known concentration of a target analyte(s). The spiked sample is processed through the entire analytical procedure. Analysis of the matrix spike is used as an indicator of sample matrix effect on the recovery of target analyte(s).

- A matrix spike duplicate is a second sample aliquot fortified with a known concentration of a target analyte(s). The spiked sample is processed through the entire analytical procedure. Analysis of the matrix spike duplicate is used as an additional indicator of sample matrix effect on the recovery of target analyte(s) as well as an indicator of method precision.

- The ongoing precision and recovery (OPR) samples must show acceptable recoveries, according to the respective methods for data to be reported without qualification.

Laboratory QC and associated control limits are summarized in Table 9. These QC samples will be analyzed at a frequency of one per analytical batch of 20 or fewer samples.
Table 9. QC Samples and Control Limits

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Method Blank</th>
<th>Lab Duplicate (%RPD)</th>
<th>Spike Blank (% Recovery)</th>
<th>Matrix Spike (% Recovery)</th>
<th>Lab Control Sample (% Recovery)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH&lt;sup&gt;a&lt;/sup&gt;</td>
<td>NA</td>
<td>+/- 0.2 pH units&lt;sup&gt;b&lt;/sup&gt;</td>
<td>NA</td>
<td>NA</td>
<td>98-102</td>
</tr>
<tr>
<td>Total suspended solids</td>
<td>&lt;MDL</td>
<td>25</td>
<td>NA</td>
<td>NA</td>
<td>80-120</td>
</tr>
<tr>
<td>Total organic carbon</td>
<td>&lt;MDL</td>
<td>20</td>
<td>80-120</td>
<td>75-125</td>
<td>85-115</td>
</tr>
<tr>
<td>Dissolved organic carbon</td>
<td>&lt;MDL</td>
<td>20</td>
<td>80-120</td>
<td>75-125</td>
<td>85-115</td>
</tr>
<tr>
<td>Orthophosphate phosphorus</td>
<td>&lt;MDL</td>
<td>20</td>
<td>80-120</td>
<td>75-125</td>
<td>85-115</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>&lt;MDL</td>
<td>20</td>
<td>80-120</td>
<td>75-125</td>
<td>85-115</td>
</tr>
<tr>
<td>Total nitrogen</td>
<td>&lt;MDL</td>
<td>20</td>
<td>80-120</td>
<td>75-125</td>
<td>85-115</td>
</tr>
<tr>
<td>Total metals, dissolved metals and hardness</td>
<td>&lt;MDL</td>
<td>20</td>
<td>85-115</td>
<td>75-125</td>
<td>NA</td>
</tr>
</tbody>
</table>

<sup>a</sup> absolute difference rather than RPD
<sup>b</sup> NA – not analyzed

### 7.3 Corrective Action for QC Problems

Corrective action for field measurements and laboratory analysis will follow those described in each SOP. Examples of corrective action include:

- Re-analyzing the samples
- Re-extracting the samples
- Re-preparing of the calibration verification standard for laboratory analyses
- Re-calibrating the field equipment
- Qualifying results as described in Section 8.2

### 7.4 Audits

Audits can help verify data quality by ensuring the QAPP is implemented correctly, and the quality of data is acceptable. To verify samples are collected according to the methods described in the QAPP, the project manager will conduct a field audit by supervising at least one sampling event for this project. Documentation will include field notes and pictures taken by the project manager. The project manager will also conduct an analytical audit by a preliminary data review; comparing analytical results, including detection limits, to the QAPP-specified goals. If review of chemistry data suggests sampling or method revisions are required, outside of those allowed in the cited methods and SOPs, an addendum to this QAPP will be prepared.
8.0 DATA MANAGEMENT, VERIFICATION, AND REPORTING

This section explains the standard practices for managing, verifying and reporting data collected or analyzed as part of this study.

8.1 Data Storage

Data will not be distributed outside each lab unit or to clients until it has met the full definition of final data. “Final Data” is defined as approved data posted to the historical database (EDS) or is otherwise in its final reportable and stored format (if not a LIMS parameter). This implies the data has been appropriately peer reviewed, properly qualified and is in its final format in terms of units and significant figures.

King County will retain records of all monitoring information, including all calibration and maintenance records and all original recordings for continuous monitoring instrumentation, copies of all reports generated for this study, and records of all data used in this study, for a period of at least five years.

8.2 Data Verification and Validation

8.2.1 Analytical Data

Data reported by the KCEL, including field measurements, must pass a review process before final results are available to the client. A “Peer Review” process is when a second analyst or individual proficient at the method reviews the data set. The reviewer will complete a data review checklist which will document the completeness of the data package and if any QC failures exist. In addition to the peer review, the data will be reviewed by the technical coordinator (TC) within each lab unit or the LPM for adherence to project goals. Results of these reviews will be documented in data review checklists, DAFs, and the QA narrative.

Once data review is complete and all data quality issues have been resolved, the data in LIMS will be moved to the LIMS historical database. Signatures or initials of the reviewer(s) indicate formal approval of hardcopy data typically on the review checklist. A copy of this approved checklist should be stored with the final hardcopy laboratory data package in the unit that generated the data.

For data generated by KCEL, a QA narrative will be generated by the LPM and will summarize all QA/QC results for analytical data generated by the KCEL. This narrative will also include Field Observation Forms generated by field personnel describing sample collection conditions and anomalies. An EPA Level 2A data validation will be conducted by the project manager in accordance to the National Functional Guidelines (EPA 2016a and EPA 2016b), and qualifiers applied (Table 10).
Table 10. KCEL and EIM Equivalent Data Qualifiers

<table>
<thead>
<tr>
<th>KCEL Qualifier</th>
<th>Description</th>
<th>EIM Qualifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>Indicates that an analysis holding time criterion was not met.</td>
<td>J</td>
</tr>
<tr>
<td>SH</td>
<td>Indicates that a sample handling criterion was not met. The sample may have been compromised during the sampling procedure or may not comply with storage conditions or preservation requirements.</td>
<td>J</td>
</tr>
<tr>
<td>R</td>
<td>Indicates that the data are judged unusable by the data reviewer. The qualifier is applied based on the professional judgment of the data reviewer rather than any specific set of QC parameters and is applied when the reviewer feels that the data may not or will not provide any useful information to the data user.</td>
<td>Reported as an observation</td>
</tr>
<tr>
<td>&lt;MDL</td>
<td>Applied when a target analyte is not detected or detected at a concentration less than the associated method detection limit (MDL). The MDL is the lowest concentration at which a sample result will be reported.</td>
<td>U</td>
</tr>
<tr>
<td>&lt;RDL</td>
<td>Applied when a target analyte is detected at a concentration greater than or equal to the associated MDL but less than the associated reporting detection limit (RDL). RDL is defined as the lowest concentration at which an analyte can reliably be quantified.</td>
<td>JT</td>
</tr>
<tr>
<td>RDL</td>
<td>Applied when a target analyte is detected at a concentration that, in the raw data is equal to the RDL.</td>
<td>No qualifier added</td>
</tr>
<tr>
<td>TA</td>
<td>Applied to a sample result when additional narrative information is available in the text field. The additional information may help to qualify the sample result but is not necessarily covered by any other qualifier.</td>
<td>No qualifier added</td>
</tr>
<tr>
<td>B, or B3</td>
<td>Applied to a sample result when an analyte was detected at a concentration greater than the MDL in the associated method blank. The qualifier is applied when the sample concentration is &gt;MDL but less than five or ten times the blank concentration. The qualifier indicates that the analyte concentration in the sample may be significantly influenced by laboratory contamination.</td>
<td>B = UJ</td>
</tr>
<tr>
<td>B3 = JL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Applied to a sample result that was measured at a concentration greater than the calibration range of the method. It is applied when the detected analyte concentration exceeds the upper instrument calibration limit and further dilution is not feasible. The reported value is an estimated analyte concentration.</td>
<td>E</td>
</tr>
<tr>
<td>J</td>
<td>Applied to a sample result that is considered an estimated value.</td>
<td>J (lab data); EST (field meas.)</td>
</tr>
<tr>
<td>JG</td>
<td>Applied to a sample result that is considered an estimated value with a low bias. This will typically be applied when QC results indicate the recovery of the analyte is below the expected limits of the method.</td>
<td>JG</td>
</tr>
<tr>
<td>JL</td>
<td>Applied to a sample result that is considered an estimated value with a high bias. This will typically be applied when QC results indicate the recovery of the analyte is above the expected limits of the method.</td>
<td>JL</td>
</tr>
</tbody>
</table>
Additionally, equipment blank and oyster shell rinsate blank results will be presented in the final report. If these results indicate a problem with precision or accuracy, data qualifiers may be applied by the Project Manager based on the National Functional Guidelines (EPA 2016a and 2016b) and best professional judgment.

### 8.2.2 Flow Data

Flow measurement devices and methods will be consistent with accepted scientific practices and will be selected and used to ensure the accuracy and reliability of measurements of the volume of monitored discharges. The devices will be installed, calibrated, and maintained to ensure that the accuracy of the measurement is consistent with the accepted industry standard for that type of device. The device will be recalibrated in conformance with manufacturer’s recommendations or at a minimum frequency of at least one calibration per month for the duration of the project. Calibration records will be maintained for a minimum of three years beyond the final report. Additionally, the ISCO 730 Flow Meters have a built in compensation for instrument drift, which is detailed in the manual.

Flow data collected in association with this monitoring program will be reviewed for quality assurance purposes. These data will be examined for gaps, anomalies, or inconsistencies between the water level and precipitation data. In the event that quality assurance issues are identified on the basis of these reviews, a site visit will be performed immediately to troubleshoot the problem and to implement corrective actions if possible.

### 8.2.3 Rain Gauge Data

Rainfall data is available on the King County Hydrological Information Center (HIC) website (http://green2.kingcounty.gov/hydrology/). Rainfall from a gauge near the study site (MERC) will be used to evaluate relative storm intensity of sampling events. Rainfall is measured by a tipping bucket rain gauge recording rainfall in 0.01 inch increments. The time of each 0.01 inch tip is recorded by a data logger and transmitted to the King County hydrologic database hourly. The database generates a report of seven days of 24 hour rainfall totals for all reporting rain gauges. Designated staff examine the report daily to verify gauge function and data reasonableness. Routine site visits are made to clean and maintain the equipment and test the calibration of the rain gauge according to manufacturer’s specifications. Periods of missing record are filled with data from a nearby gauge and flagged “E”. Data for periods when the gauge is more than 10% out of calibration may be adjusted. Data logger time is checked daily by the telemetry program and adjusted if off by more than five seconds.

Rainfall data that are entered into the hydrologic database are initially flagged “P” for provisional. Final QA/QC is performed at least annually. Field notes are checked to verify rain gauge calibration. Daily rainfall totals are compared to three or four nearby sites by charting cumulative totals and visually looking for anomalies. Tabular daily totals are examined and 15-minute totals for the comparison sites are put in columns in a spreadsheet. A visual check is performed to search for periods where a funnel may be
plugged or otherwise malfunctioning, indicated by rainfall records being too regularly spaced or exhibiting unnatural intensity compared to nearby sites. These QC procedures are used whenever the ongoing examination of the daily reports indicates a problem with a gauge. Rainfall data that has passed final QC is flagged “L” for Locked, meaning it cannot be overwritten without special administrator permission.

8.3 Data Reduction, Review, and Reporting

All lab and field measurements will follow the procedures outlined in the KCEL's SOPs and QA Manual. Laboratory personnel will be responsible for internal quality control verification, proper data transfer, and reporting data to the project manager via LIMS.

The final report of this study will include:

- A summary of parameter concentrations at the inlet and outlet at each sampled catch basin
- A summary of flows during sampled storm events
- A discussion of treatment effectiveness based on data analysis and comparison of influent and effluent in “treated” and “untreated” catch basins
- A discussion of the relationship between solids accumulation and solids and pollutant removal in the “untreated” catch basins
- A section discussing QA/QC for the data
- An appendix including all raw analytical data with laboratory qualifiers (described in Section 8)
- Final data will be entered into international BMP database by the close of the project
- Ecology and the City of Mercer Island representatives will provide a technical review of the final report
9.0 DATA QUALITY ASSESSMENT AND DATA ANALYSIS

After data verification and validation, the project manager will conduct a data quality assessment to ensure the data satisfies the MQOs and is of sufficient quality to meet study goals. The following list outlines the steps in this process, as described in the Data Quality Assessment Guidelines (EPA 2006):

1. Review the project’s objectives and sampling design.
   The first step in this process is to verify whether the execution of the sampling design satisfies the project objectives. Deviations from the QAPP and site condition anomalies will be considered as part of this step.

2. Conduct a preliminary data review.
   By reviewing the QA reports and data validation memos, the project manager can assess whether the goals of precision, bias, sensitivity, accuracy, representativeness, comparability and completeness have been achieved, as defined in Sections 3 and 4 of this QAPP. The project manager will then explore the data by generating summary statistics and basic graphs. Any observed anomalies will be investigated. Rejected data will not be used in data analysis, but will be described in the report.

3. Select the statistical method.
   The LIMS MDL value (sample-specific) will be used as a surrogate for any non-detect results. In general, this results in a high bias, which will be addressed as appropriate in the final report.

   A rank sum test will be used for comparison between inlet and outlet time-weighted concentration results, with a Wilcoxon signed-rank test for the individual enhanced treatment features, as recommended by Ecology (2010). Since the individual features are expected to reduce contaminant concentrations, a one-tailed test may be appropriate; however, if the preliminary data review suggests a possible increase in contaminant concentration, a two-tailed test will be used. Two-tailed tests may also be used for comparing the new dataset to historical stormwater quality data. The project manager may decide not to include statistical analysis for parameters with low frequency of detection, due to increased uncertainty.

   If results are similar across a given treatment type, they may be pooled by storm event for statistical analysis, in order to increase statistical power. This will be based on best professional judgement, but any conclusions will be qualified, acknowledging these are not true replicates, despite comparable design and stormwater input.
4. Verify the assumptions of the statistical method.

The distribution of the datasets will determine whether parametric or non-parametric statistical tests will be implemented. Permutation tests may be used in lieu of non-parametric statistical tests. The number of samples proposed for this project is not based on a power analysis, but instead on the maximum number of samples that can feasibly be collected by field personnel. If variability is high within the dataset, it may result in low statistical power, meaning lower probability of detecting differences between populations (e.g., inlet vs. outlet sample results).

5. Draw conclusions from the data.

In this step, statistical tests will be conducted and uncertainty of the results will also be assessed. In the final report, visual representations of the data may include scatter plots, box plots or bar charts with error bars representing standard deviations or confidence intervals. The report will also include descriptions and detailed interpretations of the statistical results. The regional applicability of the major report findings will be discussed. Lessons learned and other suggested amendments to the sampling design for future use will also be discussed.
10.0 REFERENCES


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