Washington State Department of Ecology

Standard Operating Procedure for Automatic Sampling for Stormwater Monitoring

Version 1.0

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SIGNATURES ON FILE

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Although Ecology follows the SOP in most instances, there may be instances in which Ecology uses an alternative methodology, procedure, or process. Any deviation for the SOP should be documented.

SOP Revision History

Revision Date	Rev number	Summary of changes	Sections	Reviser(s)

Washington State Department of Ecology

Standard Operating Procedure for Automatic Sampling for Stormwater Monitoring

1.0 Purpose and Scope

1.1 This document is the Department of Ecology's Standard Operating Procedure (SOP) for collection of stormwater samples using automated equipment. This SOP is designed to be used for in-pipe stormwater discharge sampling and covers a variety of technologies. Most but not all steps may also be used for open channel installations.

1.2 This SOP applies to those activities that involve the programmable automated collection of composite water quality samples. The purpose of this SOP is to provide general guidelines and procedures on how automatic samplers work, how to install and program the instruments, and sample collection and processing procedures.

1.3 This SOP describes programming and collection procedures when using automated samplers, (in common terms) for both flow-weighted and time-weighted sampling and base flow compositing.

2.0 Applicability

2.1 Storm runoff and base flow are collected and transported through natural channels, ditches, culverts and engineered pipe and treatment systems. Each monitoring site will have individual characteristics that require a specific configuration of equipment and installation that best enables the collection of representative water quality samples. A successful location for automatic samplers features stable hydraulics and the ability to install sampling equipment. Other important factors include selection of a water quality monitoring site representative of a specific land use or activity, and if calculating pollutant loadings, selecting a location that provides accurate (as defined in the project QAPP) determination of flow (water quantity) in addition to water quality.

2.2 When sampling runoff or BMP influent/effluent, care must be taken to obtain samples from points that are not affected by pre-water quality treatment.

2.3 Additionally, groundwater, back water conditions or tidal influences and interactions should be avoided in the stormwater sample and may require further modification of these procedures.

2.4 Automatic samplers can be configured to collect composite samples to reflect a mean water quality concentration. Composite sampler configurations can include:

2.4.1 Constant Time/Volume Proportional to Flow Rate or Flow Increment.

2.4.2 Constant Time/Volume Proportional to Flow Volume Increment.

2.4.3 Constant Time/Constant Volume (EPA, 1992).

2.5 Automatic samplers may not represent the complete range of particle sizes in water. Automatic samplers are not capable of sampling bed load material and are less effective in sampling larger particles. They can be effective in representing particles up to about 250 µm if the sampler intake is suitably located to collect subsamples from a well-mixed sample, such as from a cascading stream (SSFL, 2008).

2.6 Bed load samples and special floatable capture nets may be needed to supplement automatic samplers if information for the complete range of solids is needed (SSFL, 2008).

3.0 Definitions

3.1 **Automated Sampler**: A portable unit that can be programmed to collect discrete sequential samples, time-composite samples or flow-composite samples (WCD, 2007).

3.2 **Base flow**: flows occurring in the drainage after 48 hours with no measurable rainfall or less than 0.02 inches (City of Tacoma).

3.3 **Best Management Practice (BMP):** Physical, structural, and/or managerial practices that, when used singly or in combination, reduce the downstream quality and quantity impacts of stormwater (National Research Council, 2008).

3.4 **Composite Sample**: Used to determine "average" loadings or concentrations of pollutants, such samples are collected at specified intervals, and pooled into one large sample, can be developed on time, flow volume or flow rate. Four types of composite samples can include:

3.4.1 **Constant Time/Volume Proportional to Flow Rate**: Samples are taken at equal increments of time and are composited proportional to the flow rate at the time each sample was taken (Appendix A, Figure 1). This type of composite sample would typically require manual compositing of sub-samples taken from each time-series aliquot (collected manually or by auto sampler) based on a flow meter record , and require using only the instantaneous flow rate at the time each aliquot was collected (a spreadsheet is needed to do this). A fully-automatic flow weighted composite sample of this type is not typically used or even possible with an auto-sampler/flowmeter. This is also commonly referred to as a flow weighted composite sample.

3.4.2 **Constant Volume/Constant Flow Volume Increment**: Samples of equal volume are taken at equal increments of flow volume and composited (Appendix A, Figure 2). This type of composite sample is most often used and can be completely automated using conventional auto sampler and flow meter pairs, and does not require manual compositing of sub-sample aliquots unless for other special purposes, such as a paired set of time-series samples to complement the composite sample. This is also commonly referred to as a flow proportional composite sample.

3.4.3 **Constant Time/Volume Proportional to Flow Volume Increment**: Samples are taken at equal increments of time and are composited proportional to the volume of flow since the last sample was taken (Appendix A, Figure 1). This type of composite sample would typically require manual compositing of sub samples from time-series aliquots (collected manually or by auto sampler) based on a flow meter record, and require totaling the flow volume increments between sampling (a spreadsheet is needed to do this). A fully-automatic flow weighted composite sample of this type is not typically used or even possible with an auto-sampler/flow meter. This is also commonly referred to as manual flow proportional compositing.

3.4.4 **Constant Time/Constant Volume**: Samples of equal volume are taken at equal increments of time and composited to make time-composite an average sample. This method is the simplest and does not require flow measurement, but it does not yield a flow-weighted composite. This type of method may be well suited for certain special studies including toxicity assessments. However, this method is not consistent with the current stormwater permit application regulations (EPA, 1992) (Appendix A, Figure 4). This is also known as a time composite sample.

3.5 **Confined Space Entry Site** – A space that is large enough and so configured that an employee can bodily enter and perform assigned work, has limited or restricted means for entry or exit (for example, tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry) and is not designed for continuous employee occupancy (OSHA, 2009).

3.6 **Conveyance System**: A single pipe or series of pipes that convey stormwater as part of a municipal separate storm sewer drainage system (EPA, 2008).

3.7 **Drainage Area**: The area contributing runoff to a single point measured in a horizontal plane, which is enclosed by a ridge line (National Research Council, 2008).

3.8 **Event Mean Concentration (EMC):** Pollutant concentration of a composite of multiple samples (aliquots) collected during the course of a storm. The EMC accurately depicts pollutant levels from a site and is most representative of average pollutant concentrations over an entire runoff event (SSFL, 2008).

3.9 **Event Mass Load (EML):** calculated by multiplying event mean concentration (EMC) by event runoff volume.

3.10 **Hydrograph**: A graph of runoff rate, inflow rate or discharge rate past a specific point as a function of time (National Research Council, 2008).

3.11 **Hyetograph**: A graph of measured precipitation depth (or intensity) at a precipitation gauge as a function of time (National Research Council, 2008).

3.12 **Mean Concentration (MC)**: either the arithmetic mean or the flow-weighted mean of instantaneous concentrations for a pollutant parameter. Flow-weighted mean is the flow-rate weighted average of instantaneous concentrations corresponding to the measured runoff flow rates (Stormwater, 1995).

3.13 **Outfall**: Point source where an effluent or municipal separated storm sewer system discharges into receiving waters (EPA, 1992, Ecology, 2009).

3.14 **Pollutant Load**: A mass concentration multiplied by the total volume of water passing by a certain point in time.

3.15 **Stormwater**: That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, channels or pipes into a defined surface water channel or a constructed infiltration facility. According to 40 CFR, part 122.26(b)(13), this includes stormwater runoff, snow melt runoff and surface runoff and drainage (National Research Council, 2008).

3.16 **Time of Concentration**: The time of travel for rain runoff from the farthest point in the tributary area to the sampling location.

4.0 Personnel Qualifications/Responsibilities

4.1 All field staff will be familiar with other standard operating procedures for water quality sampling and/or trained to collect representative environmental samples. This practice will ensure that the sampling event is completed efficiently and cross-training on all aspects of sampling will have been completed. Staff must demonstrate a competency for sample collection using appropriate sampling equipment and techniques.

4.2 The field lead directing sample collection must be knowledgeable of all aspects of the project's Quality Assurance Project Plan (QAPP) and/or project goals and objectives to ensure that credible and useable data are collected.

4.3 All field staff will have OSHA's 8-Hour Confined Space Entry certification if confined space entry is required to access the sampling location, perform maintenance and/or sample collection.

4.4 Other training requirements may be necessary depending on situations encountered at each site.

5.0 Equipment, Reagents, and Supplies

5.1 Automated sampler.

5.2 Flow rate recording equipment is highly recommended to be installed with flow monitoring equipment.

5.3 Portable computer or data transfer unit.

5.4 Automatic sampler unit's bottle configuration section.

5.5 Pre-cleaned Suction intake tubing (Teflon® or Teflon®-lined) and hose clamps.

5.5.1 For the suction intake tubing, Teflon® or Teflon®-lined tubing is required if organic analysis because of its inert properties. Polyethylene is acceptable for non-organic analysis, however silicone-rubber tubing is used through a peristaltic pump. To determine the length of tubing needed, see Section 6.3.1.

5.6 Mounting ring for holding tubing within a piped system.

5.7 Anchors or anchoring system (stainless steel plate or bands) to secure tubing in place.

5.8 Stainless steel inlet strainer.

5.9 Power source (deep cycle RV/Marine battery, rechargeable battery, AC power source or solar-powered batteries) and connector cables.

5.10 Water quality instrument and probe (pH/conductivity/temperature meter and probe).

5.11 Triggering equipment (liquid level actuators are sometimes used for flow-proportional composite sampling as a trigger for sample collection.

5.12 Miscellaneous tools (knife, scissors, flat-head and Phillips screwdrivers, portable battery-powered drill and drill bits, a measuring tape, rope, duct tape, ty-raps and diagonal cutter, survey tape, fluorescent spray paint, and extra batteries for instruments).

5.13 Safety and personal protective equipment (flashlights and head lamps, dry chemical hand-warmer heat packs, hand sanitizer, hart hats, safety glasses/goggles, disposable gloves, earplugs, first aid kit, traffic safety cones, and high visibility safety clothing).

5.14 Site access tools (shovel and brush removal tools, manhole hook and sledge hammer, waterproof boots and waders).

5.15 Documentation/field recording equipment (writing instruments, clip board, *Rite-in Rain*™ field sheets/notebook, laboratory Chain-of-Custody (COC) forms).

5.16 Decontamination and sample processing equipment (de-ionized water, large plastic bags, ice and plastic barrier, clean, non-metallic ice chest, corn or churn splitters, decontaminated sample bottles either Teflon®, glass or polyethylene but based on parameters to be sampled).

5.17 Confined Space Entry Equipment, if applicable, portable multi-gas meter, full body harness, ventilating blower and power source, 3-way rescue and recovery tripod and winch system. Other materials needed for confined space entry as specified in OSHA Occupational Safety and Health Standards 1910.146 and Washington Administrative Code 296-809.

6.0 Summary of Procedure

6.1 Monitoring Site Selection

6.1.1 Select a representative site to ensure data is collected which best represents the storm runoff condition through the stormwater conveyance.

6.1.2 A representative sampling location should include a stormwater outfall location where stormwater is relatively well mixed and relatively “stable” or “uniform”. For selecting sites with uniform flows, avoid steep slopes, junctions, confluences, grade changes, and areas of irregular channel shape due to breaks, repairs, roots, debris, etc. Sites with pipe slopes less than 2% typically have uniform flows.

6.1.3 Select sites where the channel and storm drains are soundly constructed and have free-flowing (gravity flow) conditions.

6.1.4 Avoid selecting sites affected by backwater and/or tidal conditions since these areas can complicate measurement of flow and the interpretation of data.

6.1.5 For selecting BMP sites, determine the total number of inlets and outlets. If more than one, additional samplers may be needed to characterize multiple inlets/outlets.

6.1.6 Ensure the influent sampling station will not include any prior treatment of stormwater upgradient from the station.

6.1.7 Obtain permission (if applicable) for site access (Ecology, 2007) and conduct a follow-up site inspection during dry and wet weather.

6.1.8 Note the following information for each selected monitoring site in field notebooks:

6.1.8.1 The contributing drainage area flowing to the site.

6.1.8.2 The discharge tributary system (discharge to receiving water or other area).

6.1.8.3 Site constraints or safety concerns .

6.1.9 Dry and Wet Weather Inspections.

6.1.9.1 During dry weather, inspect the site for base flows (dry weather flows, presence of debris, signs of staining, odors, discoloration in water, unusual flows and/or excessive sediment deposits. Note observations in field notebooks.

6.1.9.2 During wet weather, inspect the discharge flow condition to get a sense for sampling conditions during storm runoff events. Note observations in field notebooks.

6.2 Delineating the Drainage Area to the Monitoring Site

6.2.1 Delineate the drainage area by determining which areas drain to the monitoring location. The delineation will help identify potential sources from land uses/contributing area, estimate the time of concentration and establish jurisdictional authority. This will likely be an important part of identifying stakeholders in the watershed or sub-basin (Ecology, 2007).

6.2.2 Obtain drainage system information from the local jurisdiction (piping and/or stormwater conveyance system, source maps, GIS files and Auto Cad files).

6.2.3 For delineating your drainage area, surface water drainage from the landscape typically follows topography in most areas, with a common exception being urban areas (Ecology 2007). However, in some instances, stormwater conveyance systems are designed to pump up hill to tie into drain pipes.

6.3 Equipment Installation

6.3.1 For installation of the suction tubing intake, meter probes and triggering equipment, locate the appropriate place at the monitoring station for representative placement. The selected area should be an area where the runoff stream is adequately well mixed to ensure representative sampling from the entire cross section of the conveyance system (typically mid stream in the pipe/channel). The suction tubing intake, other parameter probes and sampler triggering devices must be placed downstream of flow monitoring devices in such a matter as to not create turbulence which can influence flow measurements.

6.3.2 Prior to installation and equipment handling, wear clean, powder free gloves and practice clean handling techniques.

6.3.3 Cover the end of the suction intake tubing with new aluminum foil, tape or laboratory grade cellophane to prevent contamination during installation.

6.3.4 If confined space entry is required to install the suction intake, insure field staff is properly trained and certified.

6.3.5 Place the intake tubing in the stormwater conveyance system where it will best represent runoff through the system providing at least 2" of depth or greater for the intake. The suction intake must be covered during sampling to avoid improper aliquot collection.

6.3.6 For placement of the suction intake in less than 2 inches of water, a depth can be created by constructing a deeper pool using sandbags, weirs or flumes.

6.3.7 Take caution when placing any constriction in the pipe since it can also cause sedimentation which can cover the intake and affect the aliquot volume collected.

6.3.8 If constricting items are used, provide regular maintenance and checks to keep the sampler intake free of debris and sedimentation.

6.3.9 If necessary, mount the suction intake slightly above mid stream on one side of the pipe/channel if high solids loadings (bed load, trash, debris) are present. However, with the suction intake offset of the mid channel, low flows may not completely submerge the strainer.

6.3.10 Place the suction tubing mid stream, facing upstream, parallel to the water flow and downstream of the flow measuring device. The line should not be placed in an eddy or area of flow disturbance (WCD, 2007).

6.3.11 Place the line to avoid disturbance or turbulence in the flow pattern (this could interfere with flow measurements).

6.3.12 Prevent clogging by adjusting the tubing at an angle.

6.3.13 Use an anchor system or anchors to secure the tubing. Some manufacturers have a mounting plate available to mount the tubing and other probes in the channel or pipe.

6.3.14 Anchor the line to prevent bending/crimping during high velocity storm flows within the pipe/channel. Place an anchor every 20 inches for higher-velocity flows.

6.3.15 Ensure there are not kinks or dips in the tubing which can hold residual amounts of liquid or deposited sediments that could cross-contaminate sample volumes (WCD, 2007).

6.3.16 Attach a strainer to the end of the pre-clean suction intake tubing. Slide the end of the strainer into the tubing and secure it with a stainless steel hose clamp.

6.3.17 Cut the tubing to the desired length in 1 foot increments and cap the end with new aluminum foil, tape or laboratory grade cellophane to prevent contamination.

6.3.17.1 The minimum length of the pump tubing must be used to minimize the contact of the sample water and tubing as the sample water is carried from the intake tubing into the sample containers. See the manufacturer documentation on the technical limits for the automatic sampler pump and the recommended maximum length of tubing, and for limitations in elevation difference between pickup point and sampler.

6.3.17.2 If the sampling program is long-term, the suction intake tubing can remain in-place for extended periods, however, provisions must be made for flushing the tubing thoroughly with deionized water before each sampling event and with site water (deionized or ambient water) before each aliquot is drawn. It is recommended to replace the tubing periodically, semiannually or annually, depending on site conditions, project QAPP, and experience with specific tubing. Frequency of replacement and methods used for cleaning of the tubing should be support with collection of quality assurance/quality control (QA/QC) samples.

6.3.18 Measure the entire length of tubing since this information is needed when programming the automated sampler. Record measurements in field notebooks (WCD, 2007).

6.3.19 Install all other appropriate probes and/or sampler triggering device near the suction intake tubing placement.

6.3.20 All equipment installed within the stormwater conveyance systems should be secured in a way to not create turbulence and not to dislodge from the sampling location. Turbulence can create cavitations (air pockets) around the suction intake which varies the volume of water sampled for each aliquot.

6.3.21 For installation of the automated sampler, place the sampler on a level surface as close to the sample intake as possible. See the manufacturer documentation on the technical limits for the automatic sampler pump including vertical pump height and the recommended maximum length of tubing. It is recommended that the vertical distance be a maximum between 26-28 feet depending on equipment used. The sampler should never be placed at a height below the sampler intake. This situation would create a siphon

6.3.22 When sampling for metals, only stainless steel fittings or clamps should be used in all areas of sample contact. Other metallic hardware (plates, fittings, conduit and clamps) should not be used in areas of sample contact. Take care to ensure that the ends of all tubing do not touch any object that is not known to be clean during installation. Metallic hardware can be used only in areas where contact with the sample doesn't occur e.g., anchors used on the outside of the tubing.

6.3.23 For above-ground enclosures, install housing/enclosure for the equipment well above the highest water level expected.

6.3.23.1 Secure enclosure in such a manner to prevent tipping, vandalism, or theft.

6.3.23.2 Use electrical metal conduit, plastic conduit or a water pipe to protect the length of sample intake tubing from sampling point into the enclosure. Make sure the conduit is large enough to accommodate all connection cables (flow meter, parameter probes, rain gauges), and that any rough or sharp edges resulting from cutting the conduit are removed by reaming or scraping.

6.3.23.3 Place the sampler on a level surface within the enclosure and lock to prevent equipment theft/vandalism.

6.3.24 For placement within a manhole or junction box, place the automated sampler either on a shelf in the manhole/catch basin junction box or hang sampler inside the manhole/catch basin. Some manufactures have suspension harnesses and other anchors commercially available.

6.3.24.1 Make sure that the sampler is above any high water level within the pipe. High water, such as surcharging or tidal water, can float the sampler damaging the sampler unit and/or its electronics and can contaminate the enclosed sample container(s) once the sampler is submerged.

6.3.24.2 Secure the sampler in place.

6.3.24.3 Install a secondary "safety line" for all equipment to prevent equipment from being lost if platform or hanger fails.

6.4 Preparing the Sampler

6.4.1 Remove the cover or top of sampler and carefully place it to the side making sure not to kink the sample intake line.

6.4.2 Prepare the base section for the desired configuration (composite bottle or sequential multi-bottle setup).

6.4.3 Place the cover back on and feed the pre-cleaned flexible pump tubing through the peristaltic pump and into the area of the sampler where the sample bottle(s) are housed.

6.4.4 Take care to ensure that the ends of the tubing do not touch any object that is not known to be clean during installation.

6.4.5 Slide the end of the sample intake tubing (at least ½ inch) into the pump tubing and secure it with a hose clamp, if necessary.

6.4.6 Connect other equipment to sampler such as flow meters, rain gauges, level actuator, and/or parameter probes.

6.4.7 Attach power source to sampler (solar, AC, battery).

6.4.8 Turn on sampler and any other equipment.

6.4.9 To check sampler function, purge the sample tubing with site water or de-ionized water to make sure the sampler is operating properly. See manufacturer's manual.

6.5 Flow-Proportional-Sampling

6.5.1 Examples of collecting a flow-proportional composite samples include sampling of the same sample aliquot volume at a predetermined runoff volume interval (e.g., one sample aliquot collected every thousand cubic feet) (i.e., volume proportioned), or collected on an even-time basis with sample aliquot volume proportional to the instantaneous flow rate (i.e., flow proportioned). This method is typically not used automatically since most equipment does not support this function.

6.5.2 Flow-proportional composite samples collect more frequently at higher flow rates and less frequently at lower flow rates (as flow rate increases, the time between aliquots decrease). This method is a direct measure of the storm's hydrograph or the relationship between the pollutant concentration and flow rate. This allows a direct estimation of event mean concentration (EMC) and Event Mass Load (EML).

6.5.3 Key parameters for flow-proportional sampling include:

6.5.3.1 Forecasted precipitation volume/amount.

6.5.3.2 Expected amount of runoff volume.

6.5.3.3 Expected storm duration.

6.5.3.4 Expected peak flow rate.

6.5.3.5 Minimum composite volume required for desired analyses.

6.5.3.6 Minimum accepted number of aliquots, sample aliquot size, and maximum bottle volume.

6.5.4 Sequential (multi-bottle) Sampling:

6.5.4.1 Sequential sampling allows for isolation of specific samples or groups of samples from specific periods of the runoff hydrograph and provides more visual indication of sampler malfunction if it occurs.

6.5.4.2 For sequential sampling, program the sampler on either flow-proportioned or time composite sampling scheme.

6.5.4.3 If each sample is collected on the flow-proportioned or time basis and if each aliquot volume sampled is uniform, the samples can be combined to represent a flow-proportioned or time composite, respectively, of the specific period of interest.

6.5.4.4 If discrete samples are collected on a time or non-uniform flow basis, a flow-proportioned composite sample could be created by splitting each discrete sample in proportion to the discrete sample's runoff volume or instantaneous flow rate at the time of sample collection.

6.5.4.5 Key parameters for sequential sampling include, but are not limited to:

6.5.4.5.1 Minimum composite volume required for desired analyses.

6.5.4.5.2 Minimum accepted number of aliquots and sample aliquot size.

6.6 Time Composite Sampling.

6.6.1 Time composite samples are collected by sampling the flow at a set time intervals (e.g., one sample aliquot collected every ten minutes). The sample aliquot volume is the same for each sample collected.

6.6.2 Key parameters for time composite sampling include:

6.6.2.1 Desired time interval.

6.6.2.2 Minimum composite volume required for desired analyses.

6.6.2.3 Minimum accepted number of aliquots and sample aliquot size.

6.6.2.4 Maximum bottle volume.

6.7 Sampler Programming

6.7.1 Automatic samplers alone or with flow measurement devices can be programmed to collect various types of samples including: time composite, flow composite, and sequential (multi-bottle) sampling schemes. Each type of equipment system has unique programming elements, however, these three elements are common to all systems: flow quantity interval, total number of aliquot samples and the volume of each aliquot sample.

6.7.2 In general, the automated sampler is programmed to collect a sample aliquot each time it receives a pulse. The pulse can be either time-based or flow-based.

6.7.3 For specific, step-by-step procedures for programming the automated sampler, refer to the Manufacturer's User Manual.

6.7.4 Programs can vary between automated equipment but some elements are similar and include: start sampling (enable) and end sampling (disable) options. These options are dependent upon flow depth, flow velocity, precipitation amount, or time.

6.7.5 If tidal influences are present at the monitoring site, program the sampler to pause/disable in the middle of a storm event to avoid sampling marine water.

6.7.6 To ensure collection of representative samples, automatic samplers should be programmed to perform a back-flow purge cycle in between each aliquot collected. Purging the sample intake tube prior to collection of each aliquot also helps keep the line clear.

6.7.7 Programming for Flow-Proportional Composite Sampling.

6.7.7.1 Estimate a storm runoff volume for a specifically targeted storm event.

6.7.7.2 Calculate initial programming elements to produce representative samples for a range of storm events.

6.7.7.3 Pace the sampler to fill the composite bottle(s) at an appropriate level based on the forecasted rainfall depth of the storm.

6.7.7.4 Take caution when using storm forecasts. Inaccuracies may contribute to difficulty planning for the actual size of an incoming storm. As a result, a larger than predicted storm event may fill sample bottles too fast or if smaller than forecasted, the sample bottles may only fill partially resulting in insufficient sample volume for analysis.

6.7.7.5 For estimating storm runoff volumes, develop a rainfall to runoff relationship. If this is not possible and/or data are not available, storm runoff volumes can be estimated using computer models or mathematical equations. See Appendix B for two example methods to estimate rainfall/runoff relationship.

6.7.7.6 Refine initial estimates as actual rainfall and runoff data are collected.

6.7.7.7 For estimating the total sample volume needed from the storm event, refer to each chemical and/or biological test which has a volume requirement. Once the analytical tests are selected, the required volumes for each test plus any required QA/QC analyses are summed to calculate the total volume needed for analyses.

6.7.7.8 Bottle schematics and their volumes vary. Typically, 9.5 L (2.5 Gal) composite jars and 12 (1 L), 8 (2 L), 4 (3.7) bottle kits for sequential sampling are available. These volumes are usually sufficient for general characterization sampling.

6.7.7.9 If a greater sample volume is required, modification to the sampler may be necessary, two samplers can be used at the one location or field staff may have to be present on site to replace filled bottles. This set-may require special equipment programming and it is recommended to contact the equipment manufacturer.

6.7.7.10 Determine your programming parameters (flow quantity interval, total number of aliquot samples and the volume of each aliquot sample) by using your estimated storm runoff volume and the total sample volume. These elements are as follows:

$V_r / V_{fi} \approx N \approx V_s / V_a$

V_r = total runoff volume
V_{fi} = flow quantity interval
N = number of sample aliquots
V_s = total sample volume
V_a = volume of sample aliquot

(WEF, 1993 and California DOT, 2000) (See example in Section 6.7.7.16)

6.7.7.11 First, define the number of sample aliquots needed to produce a sufficient composite sample volume that represents the runoff for the entire sampling event.

6.7.7.12 For representative sampling, it is recommended that the sample aliquot volume be a minimum of 200 milliliters, at least 10 aliquots are collected, and at least 75 percent of the total event volume is sampled.

6.7.7.13 Equipment constraints must also be considered when programming samplers. For example, if battery power is used, the battery capacity and its drain from pumping up the vertical pump distance, purging, and the volume of each aliquot pumped, limits the number of aliquots that can be pumped during a storm event. Please refer to the manufacturer's literature for pumping limitations based on the battery capacity.

6.7.7.14 Additionally, many samplers need 1-2 minutes to complete a pumping cycle (purge and sample pump). It is important to regulate the flow quantity interval such that the sampler does not have to run continuously (make sure pacing rate exceeds the expected peak flow rate). At least 5 minute intervals between aliquots is recommended to allow for a full pumping cycle and to limit drain on the sampler battery.

6.7.7.15 Most storm events will be smaller or larger than predicted, so it is impossible to always fill the sample bottle(s) each time. It is recommended to use an automatic sampler that can stop sampling when the sample bottle is full to prevent overfilling.

6.7.7.16 Example Equation: $V_r / V_{fi} \approx N \approx V_s / V_a$

Where,
V_r = total runoff volume
V_{fi} = flow quantity interval
N = number of sample aliquots
V_s = total sample volume
V_a = volume of sample aliquot

(WEF, 1993 and California DOT, 2000)

6.7.7.16.1 Example Scenario 1:
Vs = 10 liters (10,000 milliliters)
V_a = 200 milliliters
$N \approx V_s / V_a$ = 10,000/200 milliliters = 50 sample aliquots
Flow Quantity Interval
$Vfi \approx Vr/N$

If N = 50 sample aliquots and Vr, the total runoff volume is 120,000 cubic feet

Vfi = 120,000 cubic feet / 50 = 2,400 cubic feet is the desired flow quantity interval

6.7.7.17 Because of the variability of storm events, a margin of safety can be provided by setting the sample pacing that will work for a wide range of storm events. For example, program elements can be set to collect the minimum number of aliquots for the minimum desired rainfall event and the minimum composite volume required for analyses. If the storm event is greater than the minimum storm targeted, there will be sufficient volume available in the composite bottle(s) to collect aliquots for the larger event.

6.7.7.17.1 Example Scenario 2:

The minimum amount of rainfall to be sampled is 0.20 inches with the runoff volume of 120,000 cubic feet (cf). The minimum number of sample aliquots, N = 10, and Vs, total sample volume, required for all the desired analyses is 2.5 liters (2,500 milliliters):

Va = volume of sample aliquot
$Va \approx Vs/N$ = 2,500 milliliters /10 sample aliquots = 250 milliliters
Flow Quantity Interval
$Vfi \approx Vr/N$
Vfi = 120,000 cubic feet /10 = 12,000 cubic feet is the desired flow quantity interval

If the composite bottle is 9.5 liters, 38 sample aliquots can be collected with the volume of sample aliquot, Va, set at 250 milliliters.

6.8 Refining program parameters

6.8.1 Refine program parameters when actual and estimated runoff differs by a factor of 2 or more.

6.8.2 Seasonal and annual program refinements may be necessary to account for seasonal and annual variation in rainfall that affect resulting runoff from precipitation events. These variations can include rainfall intensity, soil saturation, infiltration rate, and changes in impervious areas.

6.8.3 Modify calculations by revising the runoff coefficient. However, keep in mind that there will be some variability based on the storm and basin conditions. Program refinements include optimizing flow quantity interval.

6.8.4 If the composite sample volume collected was less the minimum required, decrease the sample interval.

6.8.5 If the composite bottle(s) fills before the end of the storm, increase the sample interval.

6.8.6 Divide the actual storm runoff volume by the total number of sample aliquots to determine a new flow quantity interval.

6.9 Programming for Time-Proportional-Sampling

6.9.1 Time composite sampling is done by sampling runoff at a set time intervals (e.g., one sample aliquot collected every ten minutes). The sample aliquot volume is the same for each sample collected.

6.9.2 Key parameters for time composite sampling are as follows:

6.9.2.1 Minimum composite volume required for desired analyses.

6.9.2.2 Maximum bottle volume.

6.9.2.3 Duration of storm or event to be sampled.

6.9.2.4 Desired time interval.

6.9.2.5 Minimum accepted number of aliquots.

6.9.2.6 Sample aliquot size.

6.9.3 To program for time-proportional composites, estimate the duration of the targeted storm event.

6.9.4 Program the sampler to fill the composite bottle(s) at an appropriate rate for the predicted precipitation duration. Take caution that it is very hard to predict storm duration. If the actual duration is larger than predicted, the sample bottle(s) will fill too fast, missing the tail-end of the storm, and the samples will not represent the entire storm event. If the duration results in a smaller than predicted storm, your minimum aliquot collection criteria may not be met which could result in insufficient volumes collected for analysis.

6.9.5 Calculate total sample volume (refer to Section 6.7.7.7).

6.9.6 Estimate the forecasted storm and runoff duration.

6.9.7 Program the sampler to begin sampling as early in runoff event as practical and to continue past the end of the storm event and/or set maximum limit (e.g., 24 hours).

6.9.8 Estimate the site's rainfall to runoff relationship (refer to Section 6.7.7.5, Appendix B). If available, site specific data or a computer model can be used. Appendix B contains two examples for estimating rainfall to runoff relationship.

6.9.9 If rainfall to runoff information is unavailable, estimate the runoff duration from the forecasted storm duration, amount of rainfall, and the longest estimated time of concentration for the tributary area. The National Weather Service and/or the National Oceanic Atmospheric Administration forecasts can provide estimates of storm duration along with the amount of rainfall, usually in three hours and six hours increments.

6.9.10 Typically, the runoff duration at the site is longer than the forecasted rainfall duration. The time of concentration (Tc), for the tributary area provides a measure to ensure the pacing is set to obtain a representative sample and to ascertain if sampling of contributions from the entire basin are represented, (i.e. sampling at or near the Tc may not be representative of the entire basin). See Appendix C for examples for estimating time of concentration.

6.9.11 The minimum time to program the auto sampler is 2 times the time of concentration beyond the forecasted end time of the rain event. Refine your estimated as rainfall and runoff data are collected.

6.9.12 Determine the program parameters.

6.9.12.1 The equipment program elements, time interval, total number of aliquot samples and the volume of each aliquot sample, can be determined from the storm runoff volume and the total sample volume. These elements are as follows:

6.9.12.2 $T_r / T_i \approx N \approx V_s / V_a$

Where,
T_r = runoff duration
T_i = time interval
N = number of sample aliquots
V_s = total sample volume
V_a = volume of sample aliquot

(WEF, 1993)

6.9.12.3 First, it is important to define a representative sample. A representative sample is defined as an adequate number of sample aliquots collected to produce a sufficient composite sample volume that represents the runoff for the entire sampling event. It is recommended that the sample aliquot volume be a minimum of 200 milliliters, that at least 10 aliquots are collected, for a minimum duration of at least two times the time of concentration for the drainage area.

6.9.12.4 Equipment constraints must also be considered in setting program elements. If battery power is used, the battery capacity drains from pumping, purging, and when filling aliquots which can limit the number of aliquots taken during a storm event. Refer to the manufacturer's literature for pumping limitations based on the battery capacity.

6.9.12.5 In addition, many samplers need 1-2 minutes to complete a pumping cycle (purge and sample pump). It is important to regulate the flow quantity interval such that the sampler does not have to run continuously (make sure pacing rate exceeds the expected peak flow rate). It is recommended to program the sampler at 5 minute intervals between aliquot collection to conserve battery power.

6.9.12.6 Program the sampler to stop sampling when the sample bottle is full to prevent overfilling.

6.9.12.6.1 Example Scenario 1: $T_r / T_i \approx N \approx V_s / V_a$

V_s = 10 liters (10,000 milliliters).
V_a = 200 milliliters
$N \approx V_s / V_a$ = 10,000/200 milliliters = 50 sample aliquots
Ti ≈ Tr/N
N = 50 sample aliquots and,
Tr = 4 hours (240 minutes)

Ti = 240 minutes / 50 = approx 5 minutes is the desired time interval

6.9.12.7 Pace the sampler to include a margin of safety that works for a wide range of storm events. For example, pace the sampler to collect a minimum number of aliquots for the minimum desired rainfall duration and the minimum composite volume required for analyses. If the storm event is longer than the forecasted storm duration, there will be sufficient volume available in the composite bottle(s) to collect aliquots during the longer duration.

6.10 Sampler Enables

6.10.1 Most samplers include an "enable/disable" or "start/stop" function. Enable/disable functions can include, but are not limited to:

6.10.2 Rain gauge: The sampler enables when the first rainfall measurement is taken.

6.10.3 Water level or velocity speed: Enable the sampler when base flows or a set water level occurs. For example, the base flow at a site increases from 0 to 0.3 ft in summer due to commercial irrigation but most storms easily exceed 0.5 ft. Thus, the enable is set to 0.32 ft to prevent false enables and ensures that a true storm is sampled and not the irrigation water. Liquid level actuators are sometimes used to enable for sample collection.

6.10.4 Water quality parameters: A conductivity threshold option that exists either alone or in combination with velocity, this can be used in tidal influenced areas (disable functions such as high conductivity readings and zero or negative velocities).

6.11 Measuring Rainfall

6.11.1 It is recommended to measure rainfall at the study site using a simple tipping bucket rain gauge (Ecology, 2008). Set rainfall measurements at intervals that correlate to the flow measurements such as 5 minute, 15 minute or hourly readings.

6.11.2 As an alternative to having a rain gauge on site, use a rain gauge located within the drainage area, or websites (the National Weather Service and National Oceanic Atmospheric Administration) that contain real time precipitation forecasts. These forecasts can help provide estimates of storm duration along with the amount of rainfall to aid in staff deployment.

6.12 Storm Event Staff Deployment

6.12.1 Field crews should be fully prepared to deploy when a qualifying storm event has been forecasted. Once deployed and on site powder free gloves should be worn and clean techniques practiced.

6.12.2 Upon site arrival, field staff should perform field checks. Check battery levels/power sources, tubing and all other connections to the equipment. Additionally, pump the suction tubing with deionzied water (use at least 3x the total line volume).

6.12.3 Remove the sampler base and carefully place it to the side. Be careful not to kink the sample intake line and do not allow the exposed pump tubing end to contact hands or any other surfaces.

6.12.4 Place clean bottle(s) in the base, keeping lids on the bottles. Label each bottle with station ID and the sequential bottle number.

6.12.5 Add ice to the sampler either in the base or around the bottle(s) making sure that the ice and ice water won't come in contact with sample water, contaminating the sample.

6.12.6 Remove lid(s) and place in a clean plastic, sealable bags. Label the bag with the site location name.

6.12.7 Check sample distributor, place sampler top back on the base ensuring the pump tubing end is secure and in place.

6.12.8 Program the sampler and verify that the sampler is in "sampling mode."

6.12.9 Document all activities in the field notebook.

6.12.10 If for any reason the composite sample bottle(s) need replacement during a sampling event, the field crew should:

6.12.10.1 Pause the automatic sampler program.

6.12.10.2 Wear clean powder free gloves and practice clean sampling techniques.

6.12.10.3 Remove the sampler base. Do not allow the exposed pump tubing end to contact hands or any other surfaces.

6.12.10.4 Place lids on filled or partially filled bottle(s), and remove from sampler base. Replace with clean bottle(s).

6.12.10.5 Continue sampler program and verify that the automatic sampler is in sampling mode.

6.12.10.6 Secure sampler at site.

6.12.10.7 Document bottle(s) replacement activities in the field notebook.

6.13 Sample Retrieval

6.13.1 At the end of the storm event, deploy field staff to retrieve sample bottles.

6.13.2 Upon arrival, inspect all components of the automatic sampling system to make sure samples were properly collected. If any unwarranted conditions are found, note conditions in field notebook.

6.13.3 Check battery levels and/or power source.

6.13.4 Visually inspect the components and tubing for damage and/or clogging.

6.13.5 Download field data from the automatic sampling system, rain gauge and other appropriate equipment.

6.13.6 Wear clean powder free gloves and practice clean sampling techniques.

6.13.7 Remove the sampler base. Do not allow the exposed pump tubing end to contact hands or any other surfaces.

6.13.8 Remove sample bottle(s) or entire sampler base. It is recommended to transport sample bottle(s) to lab in the sampler base/tray or cooler for transport.

6.13.9 Handling the samples carefully, as little as possible, and by as few people as possible in order to minimize the risk of contamination.

6.13.10 Place lids on the samples.

6.13.11 Inspect bottle(s) for any problems and make note in the field notebook. Note any empty bottle(s), low sample volumes [one bottle not as full as other bottle(s) or all are low], cracked or broken bottle(s) and/or if any spillage occurred during sample collection or during bottle(s) removal.

6.13.12 Note physical characteristics of each bottle including sample turbidity and approximate liquid volume.

6.13.13 Add ice around the bottle(s) to keep them cool during transport.

6.13.14 Keep samples in dark and cool during transport.

6.13.15 Place sampler top on the base or a new base.

6.13.16 Purge the sample tubing with deionized water or decontaminate the sampler tubing using a phosphate-free detergent and rinse with deionzed water (remove wastewater properly from the site).

6.13.17 Cover the exposed pump tubing with aluminum foil, tape or laboratory grade cellophane.

6.13.18 Place the cover back on the sampler and secure the sampler in place.

6.13.19 Perform any other necessary decontamination processes, program the sampler (if applicable), finish maintenance checks etc. prior to leaving the site.

6.13.20 Secure the sampler at site.

6.13.21 Immediately transport bottle(s) to sample preparation area and/or laboratory.

6.14 Sample Representativeness Evaluation

6.14.1 Create a checklist including the project-specific criteria to evaluate whether or not samples meet appropriate storm event criteria.

6.14.2 As suggested in Ecology Publication No. 07-03-006, *Characterizing Stormwater for Total Maximum Daily Load Studies: A Review of Current Approaches*, February 2007, "representative" storm criteria can include:

6.14.2.1 Volume: No fixed maximum, 0.1 inch minimum and typical range is 0.2 to 0.75 inch.

6.14.2.3 Duration: Typical range is 6 to 24 hours.

6.14.2.4 Antecedent Dry Period: 24 hours minimum.

6.14.2.5 Inter-event Dry Period: 6 hours.

6.14.2.6 Percent of the storm captured (it is recommended that at least 75% of the storm event hydrograph is captured to best represent the storm).

6.14.3 Additional criteria is also needed including: Total precipitation of storm, entire storm event duration.

6.14.4 For sequential sample composting (taking multiple bottles and combining into one representative sample, the following two items must be determined:

6.14.4.1 Percent of the sampling event flow represented by each individual bottle.

6.14.4.2 Which of the sample bottle(s), if any, will limit the compositing of samples. For the most part, aliquots which represent a specified volume collected at a specified flow volume, are collected uniformly throughout the sampling event.

6.14.4.3 From the downloaded rainfall and sampler data, review rainfall hyetograph, runoff hydrograph, time aliquot was collected, and sampler program report.

6.14.4.4 Compare data to acceptable storm capture parameters, such as number of aliquots, percent storm captured, total precipitation of storm.

6.14.5 Make decision whether or not to analyze the sample based on qualification.

6.14.6 In cases where sample bottles have unequal sample volumes, the individual sample(s) should be composited in relative proportion. In such cases, multiple composite samples should be combined using the following equation:

$$\frac{V_n}{V_t} = P_n \quad \text{and} \quad S_t \cdot P_n = S_n \quad \text{or} \quad S_n = S_t \cdot \frac{V_n}{V_t}$$

V_n – volume of flow that passed during the collection of bottle n
V_t – total volume of flow passed during the sample collection event
P_n – percent of the total sampled flow represented by bottles n
S_t – the total volume of sample collected in all bottles combined
S_n – volume of sample contributed from bottle n toward the composite sample

6.14.7 Use appropriate sample handling techniques to minimize exposure of the samples to human, atmospheric and other potential source of contamination.

6.14.8 Use a mechanical splitter or vigorously agitate to ensure that all liquid and solid will be transferred from the sample bottle to the composite bottle.

6.15 Sample Processing

6.15.1 If the samplers are using sequential (multi-bottle) sampling, they will need to be composited to produce a single composite sample. In addition, the composite sample may need to be split into multiple containers for each analysis.

6.15.2 For processing samples, mix samples thoroughly before splitting.

6.15.3 Composite samples may be split into separate bottles by manual vigorous agitation, using a mechanical splitter such as Teflon cone Dekaport splitter or Teflon churn splitter. Consider the following limitations for these methods:

6.15.4 Splitting the composite sample with an additional step using another equipment exposes the sample to another surface which may increase the possibility of contamination.

6.15.5 If you are handling a large volume (5+ gallons), you need to properly agitate it and split into analytical bottles. It is recommended to use a mechanical splitter (Teflon cone Dekaport splitter) to ensure that the samples are split evenly into the composite bottles. This should minimize any bias that could occur when trying to agitate and pour off a certain amount of each subsample into a composite. However, this process can be time consuming, is not straightforward, and may require expensive equipment (eg. $5000 Teflon churn splitter).

6.15.6 If it is difficult to pour from a wide mouth composite bottle into a small analyte bottle you must do it carefully (slowly) which will allow settling. A mechanical splitter (Teflon churn splitter) may be used to continuously agitate a sample and split off the individual analyte bottles.

6.15.7 The preferred method of splitting should balance minimizing bias from splitting the sample and minimizing contamination from sample handling when using a mechanical splitter. The preferred method should be identified in the project specific QAPP.

6.16 Field Calibration and Maintenance

6.16.1 The success of any sampling program is dependent on proper maintenance of the equipment. Maintenance on the automated sampler and other complimentary equipment is required especially when the equipment is in place for extended periods of time or when sampling multiple events.

6.16.2 Because of the adverse operating conditions associated with sampling (exposure to extreme conditions and events), the equipment should be maintained frequently and after each sampling event.

6.16.3 Perform regular maintenance every time the sampler is set to collect a storm event. Regular maintenance includes, but is not limited to:

6.16.4 Check to make sure all connections are tight.

6.16.5 Inspect the strainer and clear it of debris and sedimentation if necessary.

6.16.6 Make sure tubing is secure.

6.16.7 Inspect sample intake tubing for kinks, cracks, biological buildup, and unusual discoloration and replace if necessary.

6.16.8 If the site to be monitored for extended period, it is recommended to replace the tubing on an annual basis. Other replacement schedules may be required, depending on the specific installation and project requirements.

6.16.9 Inspect pump tubing for wear, cracks, biological buildup, and unusual discoloration. Replace with de-contaminated pump tubing periodically.

6.16.10 Note maintenance activities in field notebook.

6.16.11 Calibrate the auto sampler every time the sampler is set to collect a storm event. Use procedures in accordance with manufacturer specifications.

6.16.12 Rinse tubing with de-ionized water, or site water (i.e., stormwater or ambient water such as base flow).

6.16.13 Check the sampler by collecting a manual sample at the desired setting using the sampler and measure its volume.

6.16.14 Check the sample bottle(s) to verify the desired sample volume was delivered to the sample bottle(s). If not, recalibrate desired sample volume.

6.16.15 Adjust the sample volume to the desired sample aliquot volume according to manufacturer specifications.

6.16.16 Note calibration in field notebook.

6.17 Sampler housing

6.17.1 If the sampler unit is removed or a new unit is placed at the site, the unit should be thoroughly cleaned/decontaminated before placement to prevent cross contamination from previous events or sites.

6.17.2 Inspect desiccant and replace if necessary. This reduces the moisture buildup in the equipment and protects the system electronics.

6.17.3 For sequential sampling, inspect the sample distribution arm and its proper operation.

6.17.4 Check all equipment batteries and replace with freshly charged batteries as necessary.

6.17.5 Note maintenance activities in field notebook.

6.17.6 Decontamination and Cleaning of Equipment (California, 2000 and FL DEP 2004). Specific procedures for decontamination are dependent on analytical parameters to be measured and should be identified in the Project QAPP. The following procedures may need to be modified to conform with a Project QAPP:

6.17.6.1 Before the onset of a new study, thoroughly clean the auto sampler unit(s) using warm soapy water.

6.17.6.2 Rinse the equipment with deionzied water and let air dry.

6.17.6.3 Replace the tubing (if not new) and rinse with deionzed water.

6.17.6.4 Clean the strainer with a brush and soapy water and rinse thoroughly.

6.17.6.5 Clean the pump tube and discharge tube by attaching the suction line and placing the end in soapy water.

6.17.6.6 Manually pump the cleaning solution through the system.

6.17.6.7 Rinse three times with deionzed water and let dry.

6.17.6.8 Clean the suction tubing using the same procedure and rinse with methanol and let dry.

6.17.6.9 Cap ends of tubing with new aluminum foil, tape or laboratory grade cellophane and place in a large sealable plastic bag.

7.0 Records Management

7.1 Keep all field notes and/or field notebook notes on file.

7.2 Be sure to save and back up any electronic notes/files/downloads collected in the field.

7.3 It is recommended to enter the notes into an electronic data system, save and backup the files.

7.4 Keep files available for at least 5 years.

7.5 When using field data forms, create an original and field test the sheet for adaptation to the field procedure. This will help to avoid comprehensive updates. Use a finalized form and update every year.

8.0 Quality Control and Quality Assurance Section

8.1 Blanks (types)

8.1.1 Field rinsate blank.

8.1.2 Equipment rinsate blank.

8.1.3 Bottle blanks.

8.1.4 Trip blanks.

8.1.5 Initial installation blank.

8.2 Duplicates (what type/how many/options)

8.2.1 Separate sampler and flowmeter.

8.2.2 Separate sampler, same flowmeter.

8.2.3 Internal duplicate.

8.2.4 Composite sample split.

9.0 Safety

9.1 There are many hazards associated with sampling stormwater. Some of these hazards include fast moving water, deep water, steep slopes to sampling sites and hostile dogs or people. Use extreme caution when exiting vehicles, walking along busy roads and approaching your sampling site.

9.2 Safety is top priority for field staff and supervisors. A site specific health and safety plan and/or a safety procedure manual will be read and understood by monitoring personnel before site visits are conducted and samples are collected.

9.3 References to help develop safety programs/manuals or site specific safety plans include (see full reference in Section 10.0, Reference Section):

9.3.1 The WSDOT Safety Procedures and Guidance Manual.

9.3.2 WSDOT Work Zone and Traffic Control Guidelines.

9.3.3 WSDOT Pre-Activity Safety Plan (Appendix D).

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9.3.5 Federal Highway Administration's Appendix B, Example Health and Safety Plan.

10.0 References

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Appendix A Figures 1-3 Types of Composite Samples

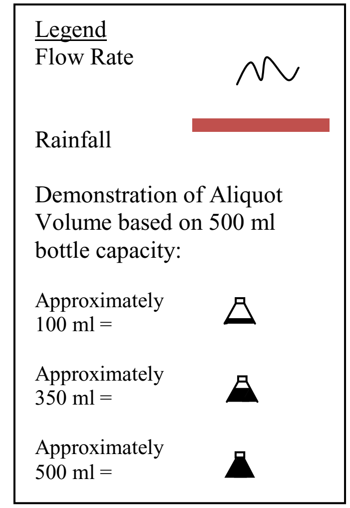

Figure 1: Constant Time/Volume Proportional to Flow Rate or Flow Increment

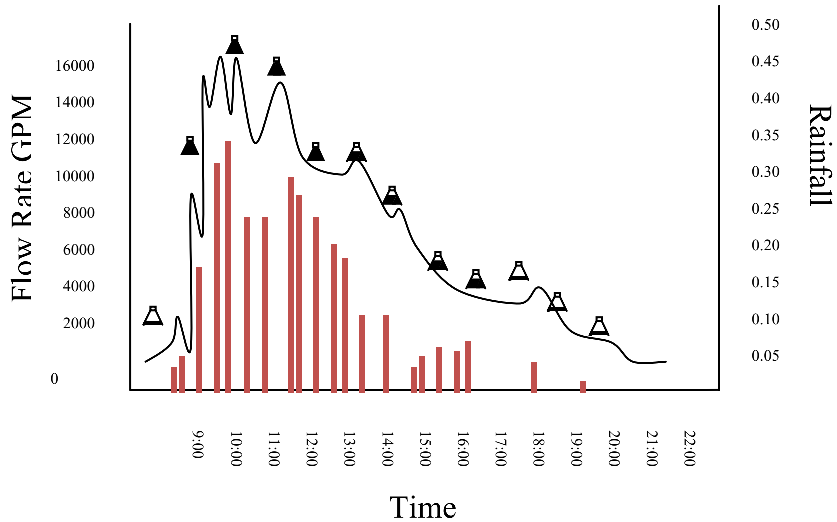

Figure 1 Notes:
Samples are taken at equal increments of time and are composited proportional to the flow rate at the time each samples was taken. Figure 3 Notes:
Samples are taken at equal

Figure 2: Constant Volume/Constant Flow Volume Increment

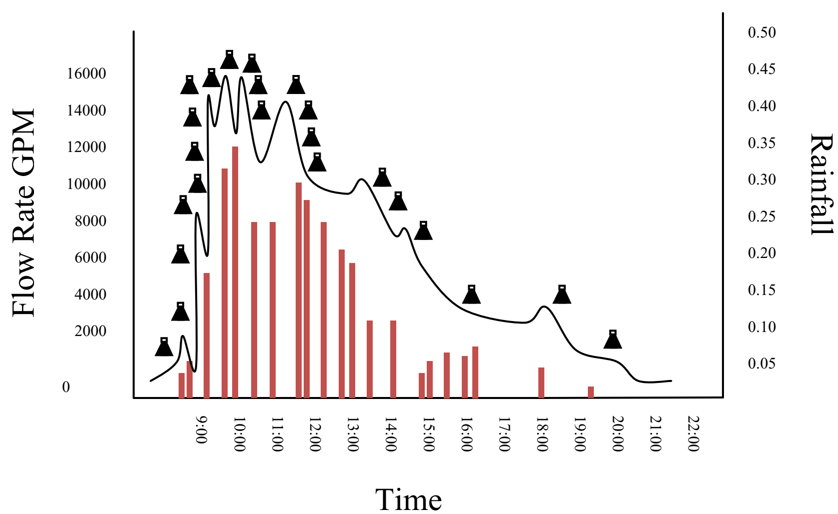

Figure 2 Notes:
Samples of equal volume are taken at equal increments of flow volume and composited.

Figure 3: Constant Time/Constant Volume

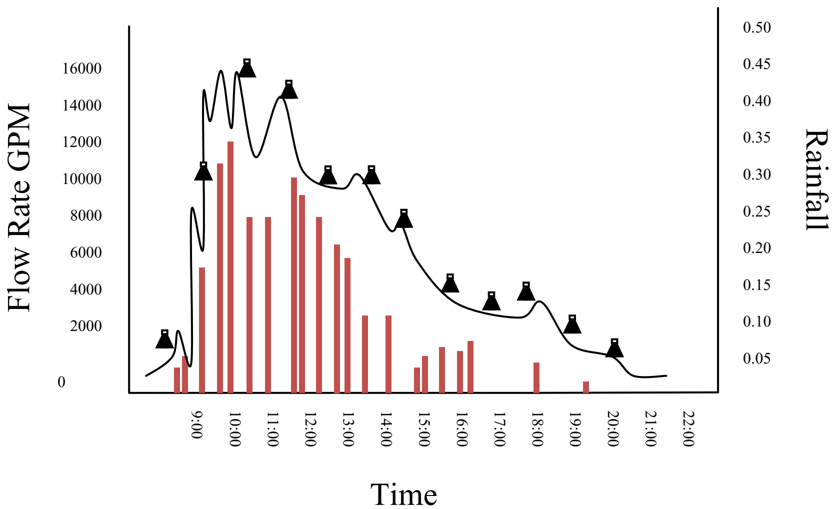

Figure 4 Notes:
Samples of equal volume are taken at equal increments of time and composited to make an average sample.

Appendix B
Estimating Rainfall to Runoff Relationship

Method 1: Estimate your monitoring site/drainage basin characteristics and average storm rainfall characteristics. One advantage of this method is that it provides establishing program elements that will work for a wide range of precipitation amounts. Average storm rainfall is the numeric average such as return frequency of a storm (e.g. Average storm rainfall may be a 5, 10 or 25-year return (i.e. to occur every 5, 10 or 25 years). Rainfall data are available from the National Weather Service.

$$Vr = \frac{PF}{12} \cdot Area \cdot RC$$

Where,
Vr = Runoff volume, cubic feet
PF = precipitation forecast, inches
Area= drainage area, square feet
RC = runoff coefficient

(WEF 1993)

The runoff coefficient (RC) is the overall ratio of runoff to rainfall. It converts rainfall data to an estimated runoff volume. The RC can be calculated based on the impervious area for the entire basin or for each type of land use within a basin.

$$RC = 0.009 \cdot IMP + 0.05$$

IMP – percent impervious

Method 1 Example:

- Drainage Area = 130 acres (5,662,800 sq feet) with 40% commercial, 20% multi-family and 40% single family land uses.
- Percent impervious for each land use is; commercial at 65%, multi-family at 45% and single family at 25%.
- Average storm rainfall = 0.43 inches

RCs
Commercial: RC = 0.009*65% + 0.05 = 0.635
Multi-family: RC = 0.009*45% + 0.05 = 0.455
Single family: RC = 0.009*25% + 0.05 = 0.257

Storm runoff volumes:
Commercial: Vr = 0.43 in (1 ft/12 in)* 5,662,800 sq feet * 0.635*40%/100 = 51,541 cubic feet
Multi-family: Vr = 0.43 in (1 ft/12 in)* 5,662,800 sq feet * 0.455*20%/100 = 18,465 cubic feet
Single family: Vr = 0.43 in (1 ft/12 in)* 5,662,800 sq feet * 0.275*40%/100 = 22,321 cubic feet

Total Runoff Volume = 51,541 cubic feet + 18,465 cubic feet + 22,321 cubic feet = 92,327 cubic feet.

Method 2: This method calculates the flow quantity for one particular precipitation event. Flow quantities can be estimated for a range of precipitation events and each used to calculate a range of program parameters.

$$V_r = \frac{PF}{12} \cdot Area \cdot RC \quad \text{or}$$

$$V_r = \frac{PF}{12} \cdot \left[\left(Area_{pervious} \cdot RC_{pervious} \right) + \left(Area_{impervious} \cdot RC_{impervious} \right) \right]$$

V_r - Runoff volume, cubic feet
PF – precipitation forecast, inches
Area – drainage area, square feet
RC – runoff coefficient, fraction of total precipitation volume delivered to the area that ends up as stormwater runoff at the point of discharge .Single number estimated to represent entire basin or percent pervious and impervious with associated areas of each.

(California DOT, 2000)

Method 2 Example:
Monitoring Site Characteristics:

- Drainage Area = 130 acres (5,662,800 sq feet) with runoff coefficient RC = 0.6
- Average storm rainfall = 0.43 inches

- Storm runoff volume:
- V_r = 0.43 in (1 ft/12 in)* 5,662,800 sq feet * 0.6 = 121,750 cubic feet

Appendix C Estimating Time of Concentration

Example Method 1: The time of concentration is estimated using SBUH methodology (Tacoma 2000). This method is described in the City of Tacoma's *Surface Water Management Manual, September 22, 2008 Edition, Volume 3* (Tacoma 2008). The Time of Concentration, Tc, is defined as:

$$T_c = T_1 + T_2 + \ldots T_n$$

$$T_t = \frac{L}{60 * V} \quad ; \quad V = k_r \times \sqrt{s_0}$$

Where:

T_c = time of concentration (minutes)
$T_{1,2\ldots n}$ = travel time for consecutive flowpath segments with different categories or flowpath slope (minutes)
T_t = travel time for each segment (minutes)
L = the distance of flow across a given segment (feet)
V = average velocity across the land cover (feet per second)
k = velocity factor (feet per second); see Table 33 with values for sheet, shallow and channel flow)
s = slope of flow path (feet/feet)

Example Method 2: Time of concentration is estimated based on methodology described in the Hydraulic Manual published by the Washington State Department of Transportation (Publication M23-03.01, March 2007) (WSDOT 2007) using the following equations:

$$T_c = T_{t1} + T_{t2} + \ldots T_{tm}$$

$$T_t = \frac{L^{1.5}}{K\sqrt{\Delta H}}$$

T_c = time of concentration (minutes)
T_t = travel time of flow segment (minutes)
m = number of segments
L = length of segment (feet)
ΔH = elevation change across segment (feet)
K = Ground cover coefficient in feet (meters)
S = slope of segment ($\frac{\Delta H}{L}$) (feet per feet)

Appendix D Pre-Activity Safety Plan

PRE-ACTIVITY SAFETY PLAN

WETLAND ASSESSMENT *(UPDATED12 MAY 09)*

SITE:

Date:____________ Employee:______________________________

1. Complete pre-travel checklist prior to travel.
2. Plan for drinking water per WAC 296-62-095
3. Review / discusses the Pre-activity Safety Plan controls for each safety hazard identified on the completed hazard assessment checklist with all staff in the field.
4. Team lead maintains completed safety hazard checklist until all have checked in with their supervisor. Save document in the project folder for the next person or time that site may be visited.
5. Fill in the registration sheet (last sheet of this document).

Location: SR_____MP_____ County ______________ Region Contact:______________________________ Phone #: (____) _____ - _________ Nearest Medical Facility: ______________________ Traffic Control Needed yes no Cell Phone Service yes no Closest phone: ______________________________ ______________________________	Parking Location: SEE PAGE 5 **Pre-Travel Checklist** ≈ **CHECK WITH REGION TRAFFIC MANAGEMENT CENTER ABOUT RUSH HOUR SHOULDER CLOSURES** ≈ **Traffic Control Plan** ≈ Environmental Safety Hazard Assessment and Mitigation Booklet ≈ Washington State Hospital List ≈ Pre-Trip Vehicle Inspection and Familiarization ≈ 1st Aid Kit ≈ Flares/Triangles/Signs ≈ Radio Contact List ≈ Emergency Contact Phone List ≈ Beacons/signage/traffic cones available in vehicle ≈ Check SR View for parking possibilities (http://www.srview.wsdot.wa.gov/home.htm)	PPE's ≈ Vest ≈ Hard Hat ≈ Eye Protection ≈ Gloves ≈ Work Boots ≈ Hearing Protection ≈ Drinking Water ≈ Hip Boots or waders ≈ PFD ≈ Throw rope bag ≈ Sunblock ≈ Insect repellent ≈ Other: ___________

Task/Hazard	Control	Site Specific Comments	Requirements
1. Walking over uneven terrain. ≈ Yes ≈ No	1. Be aware of loose material, excavation drop-offs, tripping hazards (ruts, holes, etc.), uneven ground and other obstructions. 2. Move carefully in areas with the potential for slips, trips, or falls. 3. Wear appropriate footwear with adequate traction and support.		≈ Work boots ≈ Leather gloves (Optional put recommended in areas where blackberries are dominant)
2. Working on or around rip-rap ≈ Yes ≈ No	1. Evaluate rip-rap for loose, rolling, or unstable rocks. 2. Wear hard hat and evaluate need for leather gloves when loose or unstable rock conditions exist or when there is potential for falling rocks.		≈ Work boots and gloves
3. Working in noisy area ≈ Yes ≈ No	1. Wear hearing protection if sustained noise is at or above 85db (for example next to a freeway, or if you have to shout to be heard by a person 3 feet away from you).		≈ Hearing Protection needed

* The PASP's shouldn't include medical information. If employees elect to volunteer medical information to their supervisor and/or crew that's allowed, but the supervisor and/or crew shouldn't be soliciting that information and it **should not be recorded on this form**. If a worker volunteers information to co-workers or supervisor you can discuss options if that issue arises, but if they choose not to let anybody know it's their prerogative

Task/Hazard	Control	Site Specific Comments	Requirements
4. Bridge Work ≈ Yes ≈ No	1. Reference controls for: -Walking over uneven terrain -Working around a stream -Working around natural/manmade overhead hazards -Working around fall hazards 2. Coordinate with Maintenance personnel when working from bridge structures. Follow site specific PASP as required. 3. Box girder bridges may have confined spaces requiring training.		≈ Hard hat
5. Working around bridges, signs, light fixtures, power lines ≈ Yes ≈ No	1. Continuously assess potential for falling rock or other overhead hazards, especially in windy weather. 2. When possible, avoid, restrict time in, or work during times of least activity in hazard areas. 3. When in hazard area, wear hard hat, gloves, and safety glasses along with approved vest and footwear.		≈ Hard hat, gloves, boots
6. Isolated sites / 'bad neighborhoods' ≈ Yes ≈ No	1. Consider whether location warrants two people or a team to minimize exposure time. 2. Have cell phone or check-in plan in case of emergency.		≈ Two people on site ≈ Cell phone
7. Potential for confrontation with adjacent landowner ≈ Yes ≈ No	1. Evaluate the need for informing local residents of purpose of field work. 2. If an adjacent landowner is known to be problematic, evaluate providing a written or phone notice prior to the visit. 3. If confronted by a disgruntled landowner, speak calmly and leave the site. If threatened, in addition to the above, contact police, as well as your supervisor.		≈ Known problematic land owner: Name: ____________ Location: _________ Phone #: __________
8. Potential for transients or human biohazards ≈ Yes ≈ No	1. Avoid confrontations with transients. 2. Avoid contact with human waste, needles, or other drug paraphernalia. 3. Request assistance from maintenance to remove hazard, when necessary.		
9. Potential for confrontation with a domestic animal ≈ Yes ≈ No	1. If there is a known potentially dangerous animal on or around the site, contact the person responsible for that animal prior to visit. 2. Consider carrying a deterrent such as a shovel, whistle or mace. 3. If harmed, or confronted with the threat of harm, contact animal control, as well as your supervisor.		≈ Known problematic animal: Owner: ____________ Location: __________ Phone #: ___________

Task/Hazard	Control	Site Specific Comments	Requirements
10. Poisonous snake or large carnivore hazard ≈ Yes ≈ No	1. When working in a snake or large carnivore area, consider two or more people for site visits. 2. When in carnivore habitat, make your presence known by talking, whistling, etc. 3. Stay in sight of partner or in radio contact.		≈ Two people on site ≈ Radios
11. Harmful / poisonous plants ≈ Yes ≈ No	1. Be aware of what poison ivy/oak looks like (http://poisonivy.aesir.com/ has many images and information). 2. Be aware of potential for injury from vegetation around you. 3. Bring hand-pruners and glasses to prevent injury in thick brush and briers.		≈ Hand pruners ≈ Eye protection
12. Risk of insect / invertebrate problems ≈ Yes ≈ No	1. Determine if field staff are allergic to bees or yellow jackets. Bring appropriate first aid. Confirm location of nearest hospital. 2. Listen and look for bees frequently in the air and on the surface. When spotted, inform others in the field of the location. Evaluate carefully flagging location for future visits.		≈ Person with allergy?
13. Working around natural overhead hazards. ≈ Yes ≈ No	1. Assess potential for falling rock or other overhead hazards. 2. When possible, avoid or restrict time in the hazard area. 3. When in hazard area, wear hard hat, gloves, and safety glasses along with approved vest and footwear. 4. Request assistance from maintenance to remove hazard, if possible.		≈ Hard hat, gloves, boots
14. Working around fall hazards* ≈ Yes ≈ No	1. Do not work in the fall hazard area without appropriate safety equipment and training. 2. Observe fall protection rules in WAC 296-155 Part C-1**. Prepare a fall protection plan, WSDOT form 750-001, prior to performing the work		≈ Fall protection plan needed
17a. Hot weather - Is forecast is for >77 degrees? *** ≈ Yes ≈ No	1. Consider field partner. 2. Wear weather appropriate clothing. 3. Bring sunscreen and hat for sun protection. 4. Rest as needed; take off hat and vest on breaks. 5. Replenish fluids (drink 1 quart per hour). 6. Stay in sight of partner or in radio contact. 7. Evaluate team for heat-related illness and monitor for need of medical attention	Note in Safety Meeting documentation	≈ Two people on site ≈ Radios ≈ Hat, sunscreen ≈ Drink fluids
17b. Cold weather ≈ Yes ≈ No	1. In very cold/snow/stormy conditions, consider field partner. 2. Wear appropriate clothing – gloves, hat, thermal underwear, heavy jacket. 3. Stay in sight of partner or in radio contact 4. Is the vehicle equipped with chains/traction tires?		≈ Two people on site ≈ Appropriate attire ≈ Vehicle equipped with appropriate cold weather gear

** Fall hazard area: An area where you may loose your footing, slide, trip, or loose balance.
* WAC 296-155 is available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=296-155-24501
***Outdoor Heat Exposure WAC: http://www.lni.wa.gov/rules/AO06/40/0640Proposal.pdf

Task/Hazard	Control	Site Specific Comments	Requirements
18. Working in or around areas of shallow or slowly moving water ≈ Yes ≈ No	1. Evaluate water depth hazard. 2. Evaluate slippery/steep/hidden water edge conditions and need for avoidance or uphill partner. 3. Evaluate large woody debris hazard at the work site and down stream of it. 4. Assess depth of mud and evaluate safe exit. 5. Evaluate potential rescue options that are safe for the rescuer. When warranted, establish person with throw rope bag down slope of work area and between work area and any downstream hazard.		
19. Working <u>around</u> a stream defined as a water hazard (currents greater than 10cfs or deeper than 1-ft) ≈ Yes ≈ No	1. Evaluate potential rescue options that are safe for the rescuer. 2. Evaluate need for additional support from maintenance, bridge boat, or dive crews. 3. When appropriate, establish person with throw rope bag down slope of work area and any downstream in-channel hazard.		≈ Throw rope bag ≈ Hip boots or waders ≈ PFD
20. Working <u>in</u> a stream defined as a water hazard ≈ Yes ≈ No	1. No wading under hazard conditions without safety equipment and training or specialized crews. 2. For in-water work, wear hip waders, tight-fitting neoprene chest wader, or equivalent. In rocky areas, boots with slip resistant felt-like material soles are recommended. 3. Wear personal flotation device in swift/deep water conditions.		

Tool Used	Control	Site Specific Comments	Requirements
1. Shovel	1. Wear gloves, keep handles in good condition or replace.		≈ Gloves
2. Soils knife	1. Point away from bodies, sheath when not in use.		
3. Shears/clippers	1. Keep fingers clear of blades		

PARKING ISSUES **IF WORK OR PARKING IS ON PAVEMENT, SEE LANE CLOSURE REQUIREMENTS IN M54-44. Copy of pertinent parts of M54-44 are in vehicle.** Park in areas that provide safe entrance and exit of the work area, do not create potential conflicts with other vehicles and equipment or fire hazard on tall grass.		
1. SHOULDER CLOSURES: Park and/or work on roadside <15 ft. from edge of pavement more than 1 hour ≈ Yes ≈ No	1. Coordinate with region Traffic Management Center about rush hours 2. Use beacon lights per WAC 204-38* requirements. **3.** Follow the signage and work provisions in the M54-44** for long duration work zones. **USE Chapter 2 - TCP 5 or 6. Keep appropriate TCP with you.** 4. Modify positions of cones if there is limited visibility or curves in road. 5. Evaluate noise level. If over 85db, use hearing protection.	≈ >1 hour = Stationary work zone**. Use signs and cones with beacon lights: TCP 5 or 6** ≈ Vest needed ≈ Hearing Protection ≈ Hard Hat
2. Park and/or work on <15 ft. from edge of pavement less than 1 hour ≈ Yes ≈ No	1. Use beacon lights if adequate sight distance per WAC 204-38*. Use signs/cones if reduced visibility 2. Follow the signage and work provisions in the M54-44** for short duration work zones - Chapter 3. 3. If high speed and volume, close shoulder as above. 4. Evaluate noise level. If over 85db, use hearing protection.	≈ < 1 hour Short Duration Work Zone, vehicle beacon lights ≈ Vest needed ≈ Hearing Protection ≈ Hard Hat
3. Traffic an issue, but parking and/or work locations are >15 ft from edge of pavement ≈ Yes ≈ No	1. Face oncoming traffic while on foot. 2. Be aware of or develop emergency escape routes. 3. Always wear appropriate high visibility apparel; minimum is ANSI class II vest. Avoid working alone. 4. Evaluate noise level. If over 85db, use hearing protection.	≈ Vest needed ≈ Hearing Protection ≈ Hard Hat
5. Walking from vehicle to work area near high-speed lane ≈ Yes ≈ No	1. When you can not face oncoming traffic while, try to be aware of what is happening behind you. 2. Be aware of or develop emergency escape routes. 3. Always wear appropriate high visibility apparel; minimum is ANSI class II vest. Avoid working alone. 4. Be especially careful of crossing lanes of traffic and uneven footing that could cause falls into traffic lanes. 5. Evaluate noise level. If over 85db, use hearing protection.	≈ Vest needed ≈ Hearing Protection ≈ Hard Hat

*WAC 204-38 is available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=204-38

** M54-44 is available at http://www.wsdot.wa.gov/publications/manuals/fulltext/M54-44/Workzone.pdf

HQ: Frank Newboles, State Workzone Safety & Mobility Manager (Policy)
Marty Weed, State Traffic Control Engineer (Technical)
Steve Haapala, State Workzone Training Specialist
Marlin Zimmerman, Traffic Operations Engineer (Training)

Registration Sheet

On-site Checklist

1.Specific concerns: allergies and injuries
2.Cell phones on site
3.Prepared for day (water jug full, clothing…)
4.bio or chemical hazards

Biologist Name and Additional Staff Initials	Date	Notes and Concerns