Sampling and Analysis Plan

Tahoe Regional Stormwater Monitoring Program

Refer correspondence to:

Alan Heyvaert
Division of Hydrologic Sciences
Desert Research Institute
2215 Raggio Parkway
Reno, NV 89512

John E. Reuter
Tahoe Environmental Research Center
University of California, Davis
One Shields Avenue
Davis, CA 95616-8803

Rick Susfalk
Division of Hydrologic Sciences
Desert Research Institute
2215 Raggio Parkway
Reno, NV 89512

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1) Project Overview and Scope

The Tahoe Regional Storm Water Monitoring Program (RSWMP) is being designed as an effort to collect the information needed for assessing progress toward achieving and maintaining TMDL goals on stormwater quality improvements. The primary purpose of the RSWMP monitoring is to collect data to support continued development and testing of the Tahoe Total Maximum Daily Load (TMDL) tools, specifically the Pollutant Load Reduction Model (PLRM) and other models that support the Lake Clarity Crediting Program (LCCP). The PLRM is used to estimate load reduction at the project scale (i.e., typically a drainage area containing a set of individual Best Management Practices [BMPs]). Clearly, calibration and validation of PLRM and other model output is critical to the integrity of the TMDL program. The Tahoe RSWMP is intended to provide information on runoff pollutant concentrations and load reductions achieved by stormwater treatment practices. There are a number of loosely coordinated efforts along these lines, and RSWMP will help to link them though a coordinated monitoring approach represented in this Sampling and Analysis Plan (SAP). This RSWMP SAP is intended to provide a set of consistent procedural and analytical requirements for the collection of stormwater runoff samples and monitoring data in the Tahoe Basin. It is a key component of the overall plan to document progress in urban water quality improvement for the Tahoe Basin. The SAP will be updated periodically to reflect changes in monitoring design and technology as the RSWMP evolves. More detailed information on the role of RSWMP and its linkage to other management tools can be found in the RSWMP Quality Assurance Project Plan (QAPP) and the Data Quality Objectives (DQO) document.

Urban stormwater monitoring efforts at Lake Tahoe must address multiple needs in a manner that is directly applicable to the implementation and management of the TMDL and the Environmental Improvement Program (EIP). Relevant data would significantly increase, and the quality of that data would improve, if monitoring and data analysis were done in an organized and integrated fashion; particularly when focused by a unified set of key management questions and program needs that are structured within a science-based adaptive management framework. This is the approach that will be taken by RSWMP to coordinate and combine data from multiple monitoring projects, which is statistically more powerful than attempting to link independent data sets collected for different reasons at different times using different techniques.

Desired outcomes of the Tahoe RSWMP program are based on expressed agency needs and stakeholder input to provide the following:

- Collection and delivery of reliable information on urban stormwater runoff from an integrated monitoring program linked directly to data needs of the Lake Clarity Crediting Program and TMDL tools.
- Implementation of appropriate and consistent methodologies for evaluating load reductions associated with BMPs and stormwater projects intended to achieve TMDL allocation targets.
- Basin-wide assessment of stormwater pollutant loading patterns designed to give resource managers, decision-makers, and elected officials a periodic report on changes in long-term water quality conditions in response to management actions.

The initial implementation of RSWMP will focus on evaluating the key questions listed below:

Question 1. Are the stormwater Characteristic Runoff Concentrations (CRCs) developed for identified land use types in the Tahoe Basin suitable for use in deriving model estimates of pollutant loading?

Question 2. Are the stormwater Characteristic Effluent Concentrations (CECs) developed for different treatment and source control practices appropriate estimates of load reduction for these BMPs?

Question 3. Are drainage area load reduction estimates from PLRM (or other model) projections verified by field data collected from the projects under consideration?

Question 4. Are pollutant loads from urban stormwater runoff in the Tahoe Basin decreasing in response to EIP and TMDL implementation, and what are the long-term trends, vis-à-vis, TMDL load reduction targets?

Each of the key questions outlined above will require a different type of monitoring, as listed in the following subsections. One of the main goals for RSWMP is to develop cost efficiencies, where practical, by using a nested approach in the monitoring design so that information developed by this coordinated program will contribute to answering more than one question at a time.

1.1 Pollutant Source Monitoring

Pollutant source monitoring will target specific land use types and provide updated information on stormwater runoff and characteristic runoff concentrations (CRCs) as needed to refine/update the calibration of stormwater management models and other TMDL tools. For example, datasets used in the formulation of the PLRM included CRCs for fine sediment

particles and the nutrients of concern related to road pollutant potential and other land uses, but these estimates were developed from limited data and in some cases may need to be refined, expanded, and validated.

1.2 BMP Design, Operation and Maintenance Monitoring

Data will be assembled by RSWMP from BMP monitoring to test performance assumptions and to provide information on fine particle and nutrient removals by distinct BMP processes or functions that exist as important elements of TMDL management tools (e.g. Lake Clarity Crediting Program, PLRM, BMP-RAM). The monitoring of specific BMPs will help quantify accurate load reduction estimates and the impacts of age and maintenance on performance. The PLRM currently relies on a limited dataset that defines characteristic effluent concentrations (CECs) for several BMP types. Additional data will be needed to refine/update the calibration of these CECs for pollutant load reduction modeling. This monitoring will also provide implementers with information needed to help design and build more effective BMPs. The monitoring associated with this task will focus on individual BMPs or a selected aggregate of BMPs.

1.3 Pollutant Load Reduction Monitoring

Data from stormwater monitoring is needed to validate the models being used to estimate load reductions from project areas. Therefore, monitoring associated with this task will occur at the sub-watershed scale, and should include runoff from multiple BMPs and restoration efforts as well as from developed lands and any undeveloped areas within the drainage. There must be a direct linkage between model output and stormwater monitoring for accurate testing of parameter calibration and model validation. Therefore, the design of this monitoring will be focused on project locations where the PLRM or equivalent models have provided predictions for pollutant loads in stormwater runoff for the drainage and have projected reductions in pollutant loading associated with project implementation.

1.4 Stormwater Status and Trends Monitoring

Selection of appropriate stormwater index sites for monitoring long-term patterns and trends in urban runoff will provide information needed to evaluate urban catchment loading estimates, and progress toward achieving TMDL targets. Furthermore, these sites will deliver long-term calibration and validation data for model evaluation, in contrast to the shorter-term project scale monitoring sites. Urban outfall sampling conducted on a probabilistic basis will identify spatial patterns in stormwater runoff characteristics and potential outliers in runoff loading characteristics to Lake Tahoe. Together these data will provide a Basin-wide

statistical evaluation of changes in pollutant reduction associated with implementation of the TMDL, and will document progress toward regulatory goals.

2) Organization and Responsibilities

The RSWMP Technical Unit will be responsible for the day-to-day implementation and function of RSWMP duties. Although the exact composition of this unit is still to be determined in a negotiated process between the regulatory agencies and urban stormwater jurisdictions, it is anticipated the unit will consist of a program manager and technical personnel that oversee programmatic QA/QC, data management, analysis and reporting.

Stormwater jurisdictions will have the option to choose the extent to which they prefer to conduct RSWMP directed monitoring with jurisdictional staff or subcontractors, in place of providing funds for monitoring by RSWMP Technical Unit staff directly.

As part of a process for adaptive management, the Technical Unit will report directly to the RSWMP Operations Committee, which is responsible for setting and prioritizing overall goals and objectives for the program. The Operations Committee in turn will work directly with the Stormwater Executive Management Team and with jurisdictional stakeholders to assure that their critical needs are represented by the program design.

See the QAPP for further details on recommended RSWMP organizational structure and process (Section 5.1 and Appendix B). Note, however, that until the negotiated design decisions and funding agreements are developed by the regulatory agencies and the urban stormwater jurisdictions, it is not practical to identify specific duties for RSWMP and jurisdictional personnel. Therefore, this section of the document will be developed in complete detail after that decision process has been completed in the context of the TMDL or an equivalent agency-directed process that will interact directly with RSWMP in periodic consideration of program objectives and data development.

3) Monitoring Locations

On April 30, 2010 the Tahoe Stormwater Executives issued a memo to the RSWMP development team requesting that identification of specific monitoring sites be postponed, pending further discussion between the regulatory agencies and the urban stormwater jurisdictions. They anticipated a negotiated process to determine the type, number and location of RSWMP affiliated BMP and stormwater monitoring sites. Therefore, this aspect of the SAP awaits future direction and needs to be part of the TMDL-directed process.

In the meantime, we have provided an example of the type of information that will be included in this section. The monitoring site shown in Appendix A is an existing installation operated by DRI for a project with the Nevada Tahoe Conservation District. It is similar to the type of installation that could be expected for monitoring at other stormwater and BMP sites. However, specifics always depend upon site characteristics and the monitoring objectives behind site selection, so this is not intended to represent any explicit installation for RSWMP.

4) Analytical Constituents

Stormwater runoff from urbanized areas may contain high concentrations of toxic metals, hydrocarbons, pesticides, bacteria, nutrients and sediments. While all of these are pollutants of concern, the available research indicates that phosphorus, nitrogen, and fine suspended sediment particles contribute most significantly to the loss of lake clarity (Reuter and Miller 2000, Swift et al. 2006). Consequently, pollutant reduction efforts (e.g., Lake Tahoe TMDL) have focused on these constituents. Recommended analytic methods are provided in Section 10.1 for the constituents discussed below.

For nitrogen, the most commonly reported types include dissolved ammonium (NH_4^+), dissolved nitrate (NO_3^-), and total nitrogen (TN). The soluble forms are most readily available for algal uptake (bioavailable). Organic nitrogen is typically measured after a Kjeldahl digestion. If the digestion is done on an unfiltered sample, the results are designated as total Kjeldahl nitrogen (TKN) and represent both the total organic nitrogen and ammonium nitrogen. When this digestion is done on a filtered water sample (usually < 0.45 or sometimes 1.2–1.5 microns, depending on filter used), the analysis represents dissolved Kjeldahl nitrogen (DKN). The difference between TKN and DKN concentrations represents the particulate organic nitrogen (PON) content. Note that analytic methods for nitrate often include the dissolved nitrite (NO_2^-) fraction. Nitrite concentrations are generally quite low in aerobic surface waters, however, so frequently it is not measured nor reported separately. Unless reported specifically as nitrate without nitrite, a dissolved nitrate concentration should be considered as the sum of nitrate and nitrite, typically reported as nitrogen concentration for that sample ($[NO_3+NO_2]$-N). Total nitrogen (TN) can be determined separately by some analytic methods, but more often it is simply reported as the sum of measured TKN and nitrate (plus nitrite) concentrations.

Phosphorus is reported in several analytically defined groups, with total phosphorus (TP) and soluble reactive phosphorus (SRP) being the most commonly measured. Methods for soluble reactive phosphorus measure the dissolved orthophosphate fraction (PO_4^{-3}),

considered readily available for algal uptake, as well as slight amounts of the less readily available condensed phosphates that may be hydrolyzed in part by the analytical method. For all practical purposes, however, SRP is generally considered equivalent to orthophosphate. When total dissolved phosphorus (TDP) concentrations are reported, they generally result from the same analytic methods as performed to yield total concentration but are conducted instead on appropriately filtered samples (< 0.45 microns), as was the case with DKN.

Total suspended solids (TSS) is a common analysis on water quality samples that represents the concentration of particles greater than a specified lower limit. Most frequently the reported fraction is greater than 1.5 microns (e.g., Whatman 934-AH glass fiber filter, nominal pore size). If pre-screening occurs (at 1 or 2 mm, for example) the TSS results would also represent particles less than that maximum size. Methods tend to differ somewhat from lab to lab, so they should always be specified when reporting results. If subsequently combusted at approximately 500°C the resulting loss-on-ignition provides an estimate of organic proportion in the sample.

Total dissolved solids (TDS) pass through the TSS glass fiber filter. These are sometimes called filterable residues, and are not generally considered part of the suspended sediment fraction (also referred to as suspended solids and nonfilterable residues). Total solids are the sum of TDS and TSS. Measurements of turbidity frequently correlate with TSS, although the relationship is usually site and event specific. Electrical conductivity correlates with TDS and higher concentrations in runoff are generally indicative of roadway and urban sources.

Suspended sediment concentrations (SSC) are sometimes reported for stormwater samples in addition to the TSS results. While results may be similar to TSS, they are determined by different methods so the data are not always comparable. The SSC analytic protocols are defined by the American Society for Testing and Materials (ASTM D3977), while TSS analytic protocols are defined by the U.S. Environmental Protection Agency (EPA 160.2) or by Standard Methods for the Examination of Water and Wastewater (SM 2540D). It is important that the exact method of analysis is specified with the results, along with details of filter type, sub-sampling technique, and any pre-screening of sample.

Particle size distribution (PSD) and the number of particles <16 μm in diameter exert an important influence on the transparency of Lake Tahoe. Measurement of these particles in urban stormwater runoff is essential for making decisions about designs for water quality treatment projects, treatment efficiency evaluation, and tracking TMDL progress. Traditional particles size analysis methods include techniques from soil science, such as sieving, pipette and hydrometer methods, as well as other approaches for measuring mass and size

distributions in diverse sample types. Given the importance of fine particles to Lake Tahoe's clarity and the observation that specific sizes of particles within the <16 µm fraction have direct effects on light transmission in water, the use of laser light scattering methods was considered appropriate for the analysis of lake water samples (since 1999), stream samples (since 2002), and urban runoff samples (since 2003) at Lake Tahoe. The current protocol for PSD measurements of fine sediments in Tahoe stormwater is provided as an addendum RSWMP document. Generally, the greater the number of size bins reported the better, particularly for the smaller size fractions. The recommended size classification scheme is based on a logarithmic scale (Log2), commonly referenced as the phi classification system (see Appendix B).

5) Data Quality Objectives

A preliminary discussion of event sampling frequency related to the data quality objectives is provided in the RSWMP QAPP. Further development awaits TMDL agency decisions on overall approach to support the TDML Management System or its equivalent, at which time this document will be updated to reflect the recommendations resulting from those decisions.

In addition to meeting the frequency of sample collection for event types, it is essential that subsequent sample analyses meet specific criteria. These analytic objectives for the Tahoe RSMWP samples are shown in Table 1. Accuracy will be determined by measuring performance testing samples, standard reference materials (SRMs), or standard solutions from sources other than those used for calibration. Precision will be determined from measurements of relative percent difference (RPD) on both field and laboratory replicates. Nutrient recovery measurements will be determined by laboratory spiking of replicate samples with a known concentration of analyte. Completeness will be represented by the number of analyses generating useable data for each analysis divided by the number of samples collected for that analysis. It is assumed that these data will be collected using RSWMP protocols and following the analytic recommendations with reporting limits shown in Section 10.

Table 1. Data quality objectives.

Parameter	Accuracy	Precision	Recovery	Completeness
Nutrients (N and P)	SRM or QCS within ±10% of true value	Field and laboratory duplicates with <25% RPD	Matrix spikes within 80 to 120%	>90%
Total Suspended Solids	NA	Field duplicates with <10% RPD	NA	>90%
Turbidity	±10% or 0.1 NTU, whichever is greater	Field and laboratory duplicates with <10% RPD or 0.1 NTU, whichever is greater	NA	>90%
Conductivity	±5%	±5%	NA	>90%
pH	±0.5 units	RPD <5% or ±0.5 units, whichever is greater	NA	>90%
Particle Size Distribution	NA	Mode of duplicates within 10% of phi value	NA	>90%

6) Field Equipment Installation, Maintenance, and Use

A typical stormwater-monitoring site will include flow monitoring, automated sample collection, continuous measurement of other parameters, a data logging device, a power source, and an equipment enclosure. Data from the flow meter is typically used to initiate water sampling based on user-selected conditions.

6.1 Automated Sampler

An automated sample collector consists of an intake strainer submerged in the source water, intake tubing to transfer the water to the sampler, flexible tubing connecting the intake strainer to an integrated pump that generates a vacuum, and a distributor arm that places the water sample aliquots into either a single central container or one of up to 24 1-liter sample bottles in the base of the autosampler.

Placement of the intake strainer is important to assure the collection of a representative sample. It should be place in the main flow. If placed too low, water samples may be dominated by heavier sediment travelling near the bottom of the pipe, culvert or channel, and the strainer may become buried by sediment. If placed too high, then the water sample may contain excess floating material and little solids. Additionally, the strainer may not be adequately submerged if placed too high.

The intake tubing can be installed in a conduit to protect it from being chewed through by animals. Care should be taken to avoid kinking the intake tubing during installation. To minimize water freezing in the line, the intake tubing should maintain a

positive gradient between the strainer and the sampler pump. Samplers are generally limited to the height at which they can lift water, typically about 30 feet. The sampler should be placed as close to the water source as possible. Extra sampler bottles should always be available to replace contaminated or damaged bottles, or to replace used bottles in the case of a larger-than-expected storm. The sampler should be orientated to allow the sample intake tubing to connect to the sampler without sharp bends or kinking. At the peristaltic pump, the intake tubing should be inserted at least half an inch into the pump tubing and secured with a clamp or cable tie. The sampler should also be calibrated to collect the desired aliquot volume, generally between 850 to 950 mL, but always less than 1000 mL to avoid overfilling bottles and creating potential cross contamination.

The sampler is controlled through a specialized computer built into the sampler or by an external data logging device. This controller is programmed to collect samples on a pre-defined sampling scheme, typically based on set time or flow volume intervals (see Sections 7.5 and 9.1). After the preset time or flow volume has been reached, the sampler will first blow air through the sample line (initial purge), then collect the water sample, and then blow air through the sample line again (final purge). Sampling will continue until all the bottles are filled. Therefore, the duration (or flow volume) between sample collections must be sufficient so that the sampler does not run out of bottles before the field team can visit the site again.

6.2 Flow Measurements

Flow measurements are required at each site, necessary for accurate sample compositing and subsequent calculation of constituent loadings. Accurate measurement of flow is typically a difficult task, generally associated with a primary flow device such as a flume, weir, or pipe. The height of the water column can be measured with sensors such as a bubbler, pressure transducer, or by an ultrasonic level meter. Water height is subsequently converted to discharge based on known flow ratings or hydraulic relationships. The exact approach selected will depend upon the conditions at a given site.

Flow meters must be calibrated prior to water quality monitoring and re-calibrated as necessary when data indicate problems that suggest calibration may be required. Calibration procedures include (a) verifying the relationship between the sensor reading and known depth of water and (b) the verification of a stage/discharge relationship for that site. It is strongly recommended that primary devices such as flumes and weirs are used where possible to ensure that consistent high quality flow monitoring results are produced and comparable among sites.

Flow monitoring sensors should be installed according to manufacturer specifications. Submerged sensors can be secured to the inside of pipes with expanding bands or other devices that provide laminar flow in the channel, as turbulence can influence flow reading accuracy.

6.3 Continuous Measurement of Other Constituents

Other constituents of interest may also be measured, including electrical conductivity, water temperature, and turbidity. Some automatic samplers are capable of reading the data streams from external sensors. Those that do not will require an external datalogger. Continuous precipitation monitoring is required within the drainage or an adjacent area for all stormwater runoff sites.

6.4 Site Infrastructure

In addition to the items discussed above, an enclosure to protect the equipment, a 12-volt power source (battery), and a solar panel to recharge the battery are also required. An external or integrated data logging device is needed to both store data and to control sampling equipment at the site. External data logging devices provide greater flexibility and the ability to run customized autosampler programs, compared to the standard set of programs supplied with some autosamplers.

Remote communication may be advantageous, when feasible, as it enables the field team to view current conditions and sensor status from the office. This reduces the number of field trips because sampling personnel can remotely evaluate site conditions and equipment status to determine when bottles need to be replaced or sensors need be cleared, and sampling parameters can be changed directly. Telemetry can also be used to make site data available on-line in near real-time to field crews and project supervisors, as well as to the sponsor, and the public, if desired.

6.5 Site Maintenance

General recommendations for overall site inspection and maintenance are summarized in the following paragraphs.

Keep a small watertight container in the housing at each site. This should contain a write-in-the-rain pad, pencils or waterproof pen (to record any maintenance work, problems, changes), Sharpie™ or indelible pen for labeling bottles, tools to affect repairs and adjust the distributor arm on autosamplers, fuses, etc.

Maintain an equipment inventory log that tracks the location and condition of sampling equipment. Tracking equipment performance is an important aspect of monitoring success. If the internal electronics, keypad, or peristaltic pump fails, the unit should be sent back to the manufacturer for repair. Always have extra equipment on hand to replace broken equipment.

Flow monitoring equipment and other sensors should be calibrated seasonally or when needed. This calibration is to assure that coefficients for calculations (manual or automated Manning's equation) are accurate. If flumes are used make sure it is level from front to back and from side to side.

Perform seasonal site inspection and maintenance. Perform biannual or quarterly maintenance, as appropriate for each site. Inspect housing unit, clean out accumulated dirt, and paint as necessary. Open or seal vents, depending on season. Wipe off sampler equipment with clean water. Apply silicon spray to locks. Verify that all hoses, strainers and electronics are in good condition. Inspect the intake strainers and flow sensors to verify proper placement and to ensure they are still secure and clean. Also verify sampling and purging volumes. Ensure stage readings are correct. For example, an electronic depth sensor would be removed and placed in a known water depth, or the depth offset is measured and changed in the data logging program.

7) Event Preparation and Logistics

All new field personnel must undergo training to become familiar with and ensure their competence with the techniques and protocols specified in this sampling and analysis plan (SAP). First, each team member must read the QAPP and the SAP in order to obtain the background information necessary for an overall understanding of the project. Field training should include a simulated “dry run” under the supervision of the project manager or sampling team leader. During the dry run, each team member should travel to all of their assigned sampling locations and run through the complete SAP.

7.1 Weather Monitoring

Weather monitoring is critical for determination of whether the upcoming event fits monitoring objectives and to prepare the sampling equipment and field crews. Weather tracking not only includes precipitation events, but also the occurrence of warmer conditions that promote snowmelt-driven events. In most cases, the National Weather Service will issue a quantitative precipitation forecast (QPF) as each storm approaches, including precipitation and storm duration estimates. Field crews must adequately prepare in advance of these events

by checking and programming equipment at each site, having clean sample bottles on hand and establishing logistical plans to visit each site during the event in order to verify proper function and the collection of sample bottles. Logistical coordination is required to assure that field tasks are carried out when necessary, including nights, on weekends, and during holidays.

If the event is expected to produce adequate runoff volume, the duration forecast is also used to select the sampling interval to be programmed into the autosampler controller. If precipitation falls short of the prediction, then there may not be enough sample collected to conduct the specified analyses. If precipitation significantly exceeds the prediction, then autosampler bottles may need to be replaced during the event or the frequency of sample collection may need to be lowered.

7.2 Event Selection Criteria

Criteria should be established prior to the start of monitoring to determine the types of events that should be sampled. This will require balancing project funding for field crew readiness and sample analysis with the number of samples required to meet project objectives. Selection criteria can include:

- Recommended minimum storm event size for each site. This can start at a minimum event size of 0.1 inches, up through a typical minimum QPF of 0.20 to 0.50 inches. A lower minimum event size may be necessary to provide for an adequate number of monitoring opportunities. Although there is considerable variability from year to year and site to site, the typical pattern at Tahoe is that about half to three-quarters of the precipitation events amount to less than 0.25 inch.
- Event type. Depending on the objectives of the sampling plan, certain types of events (e.g. intense thunderstorm, light drizzle, rain-on-snow, or snowmelt) may be targeted for sampling.
- Seasonal and hydrologic variability. The objective of the sampling plan may allow the monitoring of different types of storms under a variety of antecedent conditions and durations. It may be useful to monitor the first storm of the season to account for the build up of constituents during the dry season and then to target specific event types or event sizes.
- Sufficient sampling density to achieve representative sampling of the hydrograph. In order to achieve representative sampling, a minimum target of 10 or more samples

collected from each site during an event of 24 hours or less is required. A complete hydrograph showing the entire event from start to finish is also necessary.

- Unsafe conditions. Major snow, snowmelt, flooding, or other conditions may make conditions unsuitable to field crews to sample and maintain sampling sites.
- Holidays. Field crews may not be adequately staffed during certain holidays.

Examples of selection criteria include:

- Summer Rainstorm: Approximately 50 percent (%) or higher probability of precipitation, at least a 48-hour dry period preceding precipitation, and a minimum QPF of 0.15 inches.
- Fall Rainstorm: Approximately 70% or higher probability of precipitation, a QPF of 0.2 inches or greater, and at least a 48-hour dry period preceding precipitation.
- Spring snowmelt: Adequate snow on the ground to generate snowmelt runoff, air temperatures forecast to exceed 50 degrees Fahrenheit. Other considerations include the application of salts and traction control material and the timing of snowmelt (e.g. small weekly snowmelt events or large seasonal snowmelt events).

7.3 Sample Bottle Preparation

Have all sampling bottles and lids clean and ready to go before each storm. Be sure all bottles are in good condition to avoid leakage or contamination of all or part of a sample. All bottles should be soap scrubbed, hot water rinsed, acid washed, and rinsed with deionized water three times before use. Store bottles with caps on after washing to ensure that no contamination takes place.

Check for adequate inventory of bottles, filters and other consumable items. Anything used for sample collection and processing must be available before each storm event arrives. There is not enough time to obtain new supplies, such as filter paper, during the specified holding times.

Verify labeling and placement of bottles. All bottles should be pre-labeled to the extent possible in a dry environment before each monitoring event. Labels should be placed on bottles rather than the caps. Bottle labels can be produced using blank water-proof labels and computer labeling software. To facilitate bottle replacement, all 24 sample bottles can be replaced at one time by replacing the entire autosampler base with a new set of bottles. Verify that the bottle number on the label matches the physical bottle position. A

standardized bottle label should include the following information, with other items as appropriate:

Project Name:_____ Station Name:_____
Event Number: _____ Date and Time:_____ Sample Type:_____
Bottle ____ of ____ Collected by:_____

Label QA/QC samples. Field blank and field duplicate samples should be sent to the analytical laboratory "blind". Label these QA/QC sample with pseudonym site names and enter actual QA/QC sample information carefully into the field log.

7.4 Equipment Preparation

Assure that the autosampler, sensors, and other equipment are positioned correctly and in working order. This includes:

- Remove snow and ice from around equipment and flumes to ensure accurate measurements. Snow, especially plowed snow, can inhibit flow readings in primary flow devises (flumes, weirs, etc.) by damming or diverting the flows.
- Make sure that all sensors, intake tubes, rain gauges, and strainers are clear of debris, ice, and sediment.
- Inspect the location and condition of the strainer, the condition of the intake tubing, and assure that the intake tubing connection is secure. Loose or inappropriately attached strainers or tubing can create turbulence in front of flow sensors and produce unreliable data.
- Remove the autosampler cover and:
    - Check intake tubing for kinks or twists (straighten if found).
    - Inspect sampler peristaltic tubing for wear or breaks. Replace it if there is any doubt about its condition.
    - Verify the connection between the intake tubing and peristaltic tubing is secure and properly clamped.
    - Check all electrical connections for tightness.
- Remove the autosampler controller top and:
    - Check that the pump tubing is connected and not kinked.

  - Check that the base is filled with 24 clean sample bottles. Make sure the bottle holder is locked into place.
  - Fill the base with ice if temperatures will be above 40 degrees Fahrenheit.
  - Store the bottle lids in a clean Ziplock bag (these lids will be reused when retrieving full bottles.)
  - Regularly test distributor arm to ensure that its alignment is correct.
  - Place the top section back onto the base and shut each latch.

- Make sure that all sensors are functioning and inspect for changes in sensor placement. Assess sensor cables for chew marks or other damage, and that the sensor's electrical connections are secure. Re-calibrate sensors on an as-needed basis.
- Check batteries for charge with a voltmeter. Replace or charge the battery if it is less than 12.4 volts. Verify that the battery is being properly recharged and that all connections to the solar panels (if present) are secure.
- Check internal and external desiccant condition in the electronic components and replace before they expire or if they are no longer functioning.
- Check the enclosure vents. Open in summer to reduce overheating of samples after collection, but close in winter to help prevent freezing.
- Verify the autosampler program.
- Be certain that equipment is powered on and the program is running before leaving each site.
- Note any changes or issues in the field log at each site.

7.5 Autosampler Programming

Program the sampling interval based on storm duration and intensity estimates. This estimate will usually be based upon site-specific experience coupled with the event-specific QPF provided by the project's designated weather monitor (see Section 7.2). Based on estimated storm duration and intensity, calculate a reasonable sampling interval based on either flow volume or constant time interval. Record this information in the field log for future reference.

Program the autosampler based on the sampling interval determined above. In most cases when a constant time interval is used it will typically range from 10 to 60 minutes. For example: use a 10 min interval for events of less then two hours; a 15 min

interval for events expected to last between two to four hours; a 30 min interval for event durations of 5 to 9 hours; and a 60 min interval for events lasting between 9 and 24 hours. Depending on project objectives and availability of the field crew, longer constant time intervals may be used. Longer sampling intervals may also be used to assure that a station's battery does not become depleted. In the preferred situation where a constant volume interval is used, the runoff interval is determined from prior experience with event runoff characteristics for that site or by best professional evaluation. In either case, the objective is to collect a target of at least 10-12 samples over any event lasting less than 24 hours, and at least 10-12 samples for each 24 hour period of events lasting longer than a day.

Take extra precautions during winter operations. Make sure to keep sample strainers free of snow, ice, and sediment. Sediment deposition in flumes and primary flow structures can clog or alter the performance of stage measurement devices. Pipe insulation can be used to help minimize water freezing in the sample lines. It is also important that an adequate air purge is conducted prior to and after each sample collected to minimize water retention in the sample line. Field crews should have immediate access to extra fuses in case they need to be changed due to the sampler pump binding up on ice.

Set autosamplers to start at the beginning of runoff event. If time based sampling intervals are used, verify the minimum stage or discharge levels that will trigger sampling and verify that they these levels are consistent (and greater than) current stage or discharge readings. If flow based sampling intervals are used, make sue to reset the flow counter that triggers sampling. If start triggers are used (e.g. change in flow, level, or a specific time, etc) verify that they are set correctly. In some instances, the autosampler can be manually started just prior to runoff.

Start autosampler and verify distributor arm location. Once the above settings have been verified, the autosampler program can be initiated, typically by pressing the "<START>" button and then selecting a program. The exact process for initiating sampling varies between autosampler model and if an external data logger is used.

7.6 Baseline Sampling

It is generally recommended that a water sample be collected within a 24-hour period before an event begins to assess existing flow conditions at each site. Baseline samples should be collected using the manual sampling mode of the autosampler. Alternatively, a series of samples can be collected over a longer period and aggregated into a single composite sample, following the methods described below for compositing samples.

8) Monitoring and Sample Collection

The field crew should visit each site regularly during an event to ensure that the equipment is working properly and that the sampling interval is set to collect representative samples.

8.1 General Precautions

Safety. The field crew should always be aware of their personal safety during travel to and from sites, and during installation, operation, and maintenance activities. Always wear protective gear when necessary and carry emergency supplies. Avoid entering moving water under hazardous conditions.

Parking. Always park in a safe location and be aware of motor vehicle, bicyclist, and pedestrian traffic near the site. Road maintenance activities such as snow removal may affect the ability of field crews to park at monitoring sites. Do not park in the roadway or on the paved shoulder if the road is not plowed; find an off road parking location. If necessary, set up adequate traffic safety controls.

Equipment Access. When opening the equipment enclosure, be careful to check for spiders and wasps both in the padlock housing and inside the enclosure. Make sure that the enclosure lid is lifted until both hinges are locked. Failure to do so may cause injury.

Collecting samples. Efforts must be taken to reduce potential sample contamination, including:

- Never sample near a running vehicle.
- Avoid rainwater or snow from falling into sample bottles.
- Do not eat, drink, or smoke.
- Do not exhale, sneeze, or cough near open sample bottles.
- Samples should be collected upstream and upwind of sampling personnel, whenever possible.
- Use only pre-cleaned sample bottles for sample collection.
- The inside surface of the sample tubing, bottles or lids should never be touched or come in contact with anything other than the sample water.
- Do not allow any foreign object to fall into or come in contact with collected water samples.

8.2 Event Inspections

Many events within the Tahoe Basin produce runoff over extended periods, such that field crew must alternate between maintaining proper function of equipment, interval timing, debris removal and sample collection/bottle exchange. During the event it is usually necessary to check the following:

a) The distributor arm on the sampler is aligned correctly and sample volumes do not exceed bottle capacity.

b) Samples make it into the correct bottle without spilling.

c) The program is running correctly, not frozen or stopped, with all settings as desired.

d) Data (level, velocity, etc.) is being logged correctly. Pay special attention to the quality of flow data as samples taken without good corresponding flow measurements are not generally analyzed.

e) The sample tubing is not clogged. Sensors are free of sediment and debris.

f) Stormwater flow in the channel is not backed up.

g) The selected volume interval is producing a reasonable number of samples; increase or decrease interval accordingly. If a change is to be made, wait until a sample is taken and then increase or decrease the interval by an even increment (e.g., 200%, 50%, 25%, etc.). This will make subsequent calculations much easier.

h) Assure that there are enough empty bottles available within the sampler to last until they will be collected.

Field observations regarding sensor/sampler performance, water height/flow or other pertinent information should be recorded in the field log.

8.3 Sample Collection

When removing bottles or sampler bases, immediately cap the bottle, check their bottle labels for correct site ID and bottle/position number, and make sure that the correct bottles were indeed filled as reported by the equipment. To ensure no samples are mixed up between sites, the site ID and bottle number can also be marked on the bottle caps. Verify bottle identification and sequence before removing from the sampler site. Use indelible pens (Sharpie™) to mark labels, bottles, and caps. Note any unusual conditions or circumstances in the field logs.

Sample bottles should be checked to verify that the expected sample volume was delivered to the bottles. If the sample volume was not correct, it should be noted in the field log and recalibrated prior to the next monitoring event. Samples are transported back to the lab in coolers at constant temperature (near 4°C). Make sure bottle caps are tight, and keep bottle upright to minimize leaks. Use clear, wide packing tape to secure labels if there is any danger they may fall off in transport. Keep samples in the dark as much as practical.

After collection of all samples, the sampling event is terminated and data are downloaded from the station's data logger to either data transfer units or to a laptop computer. Always download the data when samples are collected, as these data are needed for creating composites and for calculating event mean concentrations. Verify the location and filename of the data file, and that is has downloaded successfully. Repeat a data download if there is any question about the integrity of data transfer. Once the sampler is reset, or the program modified, these data are erased on the sampler or data logger and are no longer available for download. It is strongly recommended that, whenever possible, the data are evaluated while still in the field at the site. A weather-resistant laptop computer is generally needed to conduct this field assessment, but it is extremely important that the hydrograph and sampling profile are examined to determine whether equipment adjustments are needed for continued monitoring.

As described in the QA/QC section, additional samples or sample volume may need to be collected for QA/QC purposes. Field duplicates require the collection of additional samples in quick succession. For inter-laboratory splits, greater volumes are required, typically on the order of 5 gallons. Laboratory spikes and duplicates may require the collection of greater volumes of water. Check with the analytical laboratory on the volumes of sample required.

8.4 Prior to Site Departure

Inspect the condition of all equipment, tubing, and sensors. Make sure there is no standing water in the base of the samplers, in order to eliminate the potential corrosion of sensitive electronics within the enclosure.

In the field log, note: (a) estimated sample coverage and portion of the hydrograph covered (e.g. all, first, middle, last); (b) total number of samples collected; (c) bottle numbers of samples unsuccessfully collected; (d) time when first and last samples were collected; (e) time when rainfall and runoff ended; (f) note any sediment accumulation and its location; (g) note any maintenance activities needed before the next event.

Remove any trash from the site, carefully close the housing lid, and lock up the enclosure.

9) Sample Processing and Chain of Custody

Once samples are collected they must be delivered to the lab for immediate processing and analytic preparation. Certain data must accompany this delivery, including a list of sample dates and times, sampling errors, and discharge logs. Lab personnel may also need to be notified of samples in storage for processing or analysis. There are specific holding times within which runoff samples should to be processed and specific analyses should be performed, as shown in Table 2. See the RSWMP QAPP for additional information.

Table 2. Sample bottles and holding times.

Analyte	ID	Sample Container	Preferred Holding Conditions
Soluble Reactive Phosphorus (orthophosphate)	SRP	Polyethylene sampling bottle	Filtered sample in the dark at 4°C, up to 7 days or freeze
Total Dissolved Phosphorus	TDP	Polyethylene sampling bottle	Filtered sample in the dark at 4°C, up to 28 days or freeze
Total Phosphorus	TP	Polyethylene sampling bottle	In the dark at 4°C, up to 28 days or freeze
Nitrate + Nitrite	$[NO_3+NO_2]$-N	Polyethylene sampling bottle	In the dark at 4°C, up to 7 days or freeze
Ammonia	NH_3-N	Polyethylene sampling bottle	Filtered sample in the dark at 4°C, up to 7 days or freeze
Total Kjeldahl Nitrogen	TKN	Polyethylene sampling bottle	In the dark at 4°C, up to 28 days or freeze
Total Suspended Solids	TSS	Polyethylene sampling bottle	In the dark at 4°C, up to 7 days
Suspended Sediment Concentration	SSC	Polyethylene sampling bottle	In the dark at 4°C, up to 7 days
Turbidity	Turbidity	Polyethylene sampling bottle	In the dark at 4°C, up to 7 days
Electrical Conductivity	EC	Polyethylene sampling bottle	In the dark at 4°C, up to 28 days
pH	pH	Polyethylene sampling bottle	In the dark at 4°C, up to 7 days
Particle Size Distribution	PSD	Polyethylene sampling bottle	In the dark at 4°C, up to 7 days

9.1 Composite Sample Calculations

A sample log should be created when samples are delivered to their processing site. Upload the flow and sampling data from each site onto the designated computer. This information is then compiled at the laboratory into a sample log data sheet that indicates which samples should be processed or composited. A compositing schedule should be included on this sheet as necessary.

Decide whether to create flow-weighted composite samples or analyze as individual samples. A composite sample is comprised of some number of individual sample aliquots mixed together, generally weighted by flow. The decision to create a composite sample will depend upon a number of factors including project objectives, available funds for analysis, whether the analytic laboratory has a sample backlog, and if enough samples were collected to adequately represent the event.

Minimum storm capture thresholds are set prior to the project starting and are typically based on the number of bottles collected and the percent of the overall storm that the water collected in these bottles represents. The storm capture percentage is calculated by dividing the flow volume that passed the sampling station during active sample collection by the total flow that passed the station during the entire event. Sample sets that do not meet minimum storm capture thresholds are not composited, but can be analyzed individually if needed. Other sample types, such as baseline sampling (Section 7.5) are analyzed individually.

Determining the start and stop times for composited samples. For precipitation dominated runoff events, composites are created with samples collected from when runoff started to when it ceased. Project objectives may require that the first flush of runoff is composited separately from the remainder of event. Prior to the start of the project, the definition of first flush must be determined. First flush can be determined by time (e.g. first 2 hours), by flow volume (e.g. first 2000 gallons or the initial 5% of total volume), or by changes in measured parameters such as flow intensity, turbidity, or electrical conductance.

For extended runoff events where there exists a diel pattern to runoff, such as during snowmelt, composites of between 24 and 72 hours in duration should be generated. These composites should be in even multiple of 24 hours, with their start and stop times during daily low-flow periods, typically from 6 to 10 AM. Individual samples collected daily can be immediately forwarded to the lab for preservation and storage prior to composting (depending on project objective and desired analyses).

Calculating flow weighted composites. Individual sample aliquots taken from each sample bottle are combined to create flow-weighted composites using instantaneous flow rates from each sample time. The Lahontan Regional Water Quality Control Board recommends the use of the flow rate method:

$$A_i = Q_i \Big/ \sum Q_i \times 100$$

where A_i is the individual sample aliquot, Q_i is the instantaneous flow rate at each sample time, and $\sum Q_i$ is the sum of all the instantaneous flow rates (Q_i). The instantaneous flow at sample time may need to be estimated by linear interpolation of the bracketing logged flows.

A more accurate alternative for calculating flow-weighted composites is to proportion sample aliquots by cumulative volumes instead of instantaneous flow rates. In this case, the cumulative volume of flow between each sample period (V_i) is calculated from the flow data and then used to proportion sample aliquots (A_i) for creating the composite:

$$A_i = V_i \Big/ \sum V_i \times 100$$

The drawback to this method is that cumulative volumes for each sample time must be first calculated from the flow data. The half volume interval method is a similar approach, but uses cumulative volumes at the midpoint between each sample. This method is generally the most accurate, but requires additional calculations, is labor intensive and therefore more prone to introduction of errors. When practical, the cumulative volume approach should be used, although the flow rate method is also acceptable when necessary.

The sample log sheet should indicate percentage contribution (to nearest tenth of a percent) from each sample used in creating the composite, as well as the method of calculation. Verify that contributions from all samples in the composite sum to 100.0%. Shake each sample bottle well and immediately pour the appropriate amount into a clean graduated cylinder, then add this volume to a clean, labeled composite bottle. Total composite volume is typically set to 1000 mL, but may be less if the volumes in the sample bottles are low.

9.2 Sample Processing

Sample collection for inter-laboratory splits. When inter-laboratory split samples are desired, collect water in a clean 5 gallon bucket. If sampling from an area with running water, fill the bucket from an area in which you can capture as much of the flow as possible. Be careful not to disrupt the bottom sediment or collect things floating in the water (sticks, leaves, algae, etc.). Place the bucket in a refrigerator ASAP and prepare for splitting the sample.

Churn splitter protocol for sample splits. First, rinse all churn splitter parts. Then, mix the water sample and pour into the churn splitter through a 1000 µm screen. Raise and lower the handle slowly at a uniform rate of approximately 9 inches per second. The round trip frequency should increase so the churning disc velocity stays the same as the volume in the tank decreases with sub-sample withdrawal. The disc should touch the bottom of the tank on every stroke, and the stroke length should be as long as possible without breaking the water surface. Stir the sample in the splitter at uniform rate and for at least 10 strokes before first withdrawal. Churning should be continuous during the withdrawals, requiring a second person to collect the aliquot sub-samples during churning. Sub-sample volumes should be distributed to each bottle using smaller aliquots in carousel fashion. For example, if ten 1000 mL samples are needed, distribute 250 mL to each bottle, then distribute another 250mL to each bottle, and repeat two more times. To clean the churn splitter, acid wash once, then rinse three times with DI water.

Sample Filtration and Total Suspended Solids (TSS) determination. The following procedure is to be used if TSS is measured outside of the analytical laboratory. Use clean filter towers and precombusted (at 500°C), tared 334-AH 1.5 µm glass-fiber filters or equivalent to collect a measured volume of sample or composite (generally about 250 mL). Filtration should occur within a maximum of 48 hours after sample collection; 24 hours is preferred when practical. Check filters for cracking after pre-combustion and before use.

To ensure filters stay uncontaminated and dry, all filters are to be stored in an airtight desiccator cabinet. Be sure to shake sample well before pouring into graduated cylinder. Then pass filtrate through a clean 0.45 µm nylon mesh or membrane filter. This resulting dissolved fraction sample is decanted into a clean bottle and labeled with sample ID, date, time and requested analyses (soluble nutrients). The glass-fiber filter is dried to constant weight at 60°C, and then weighed for calculation of TSS. EPA standard protocol lists no method detection limit for TSS, however an MDL of $\leq$0.4 mg/L is accepted.

Splitting samples for subsequent analysis. Shake sample to suspend particulate matter and pour off appropriate volumes into clean, labeled bottles. For stormwater samples, only 250 mL are generally needed each for total nutrients analysis and for particle size distribution of suspended sediment fractions $\leq$63 µm. Consult with the analytical lab for specific volume requirements. Do not rinse with DI to obtain residual volumes or particles as this dilutes the original concentration of each sample. Keep samples in the dark at 4°C during storage and transport.

Bottle washing. Liquinox wash and scrub, rinse soap away with hot tap water, then rinse once with a 0.1N HCL solution, followed by three deionized water rinses.

9.3 Post-Event Reporting

A post event summary report should be generated detailing general runoff and storm or snowmelt runoff conditions and the sampling performed at each site. The following information should be included:

- Event Description (start/stop dates and times, rainfall and/or snowfall amounts, snow level, etc.)
- Site/Sample Locations
- Discussion of any sampling issues
- Event flow data review

A review of the event flow data is necessary to confirm that the flow rates and volumes are consistent among all the sites monitored. This is particularly important in freezing weather when ice and ice blockages result in inaccurate flow measurements and freezing water in sample tubing can reduce the volume of water collected.

9.4 Chain of Custody and Sample Delivery

Chain of custody (COC) forms must be filled out for all samples submitted to the laboratory. At a minimum, these forms must contain a sample date, sample location, and analyses requested. An example COC is provided in Appendix C. Place COC forms in a watertight plastic bag and place in the cooler with the samples. Keep a copy of all COC forms in a binder for reference. When shipping samples, it is good practice to also include the shipper's initials, date/time shipped, and the shipping service's parcel tracking number on the COC.

Samples must be placed on ice in coolers and sent immediately for analysis of nutrients and particle size distribution in order to be analyzed within the desired holding times. Make sure that the cooler is securely closed and that the shipping label is fastened securely. It is good practice to also have a contact name and phone number visible on the outside of the cooler.

Be sure to verify that deliveries (usually overnight shipping) will be received at the appropriate time. Some labs are closed over the weekends and holidays, so samples would potentially sit undelivered and unrefrigerated. Verify that the shipment has been received either: (a) with the shipper using the parcel tracking number; (b) with a phone call to the lab, or (c) by other method pre-arranged with the analytical laboratory.

10) Laboratory Analysis and Reporting

It is important to select one or more analytical laboratories that are capable of conducting the desired analyses. Selection criteria include location, performance, ability to meet analytical reporting limits (RLs), and past experience with both the sample types and the expected concentration ranges that will be collected by the monitoring program. A local laboratory can provide logistical support by providing sample bottles, supplies, and other equipment on short notice, as well as provide sample preservation and analysis services. The analytical laboratory should also contribute to the development of sampling strategies prior to implementation by:

- Providing laboratory performance requirements such as reporting limits, turnaround times, holding times, types and frequency of laboratory QA/QC analyses, quality control performance limits, report formats, and corrective action procedures.
- Determining the sample volumes necessary for the requested analyses.
- Review and comment on the QA/QC approach, sample schedule and volume requirements for QA/QC samples.

10.1 Reporting Limit Requirements

A reporting limit (RL) is the minimum concentration at which the analytical laboratory can reliably report detectable values for a given analyte. The reporting limit must be greater than or equal to the method detection limit (MDL), which is the lowest concentration that can be detected by the analytic method. The MDL is approximately three times the standard deviation of seven reagent blanks fortified at an analyte concentration of two to three times the estimated MDL (40 CFR 136 Appendix B). In many cases, the reporting limit is 3 to 5 times greater than the method detection limit. This is common practice for laboratories reporting compliance data to monitoring agencies. Research laboratories can generally report lower limits by emphasizing the lower concentration portion of the calibration curve. Laboratories should always have their lowest calibration standard at or below the reporting limit. Analytical results below the reporting limit are expressed as "less than" the reporting limit.

Analytes monitored in Lake Tahoe basin stormwater are shown in Table 3, along with preferred analytic methods (Standard Methods, USGS, ASTM) and reporting limits. These are the methods that have been routinely used by laboratories for analysis of LTIMP and TMDL samples. While some laboratories may sometimes report at higher levels than the targeted limits shown in Table 3, they should be as close as practical or better. The

determination of MDL is required for nutrients but typically not available for pH, conductivity, turbidity, suspended solids, suspended sediment, or particle size distribution. Error (uncertainty) associated with analytical measurement is generally small (less than 20%), but this error becomes greater as measured concentrations approach the detection limits.

Table 3. Recommended analytic methods and reporting limits.

Analyte	Methods	Description	Target Reporting Limit
Orthophosphate as P (i.e., Soluble Reactive Phosphorus)	EPA 365.1; or EPA 365.2; or EPA 365.3; or SM 4500-P-E	Colorimetric, phosphomolybdate	10 µg/L
Total Dissolved Phosphorus as P	EPA 365.1 w/ USGS I-4600-85; or EPA 365.2; or EPA 365.3; or SM 4500-P-F	Colorimetric, persulfate digestion, phosphomolybdate	10 µg/L
Total Phosphorus as P	EPA 365.1 w/ USGS I-4600-85; or EPA 365.2; or EPA 365.3; or SM 4500-P-F	Colorimetric, persulfate digestion, phosphomolybdate	10 µg/L
Nitrate + Nitrite as N	EPA 353.1; or EPA 353.2; or SM 4500-NO3-F	Colorimetric, cadmium reduction	10 µg/L
Dissolved Ammonia as N	EPA 350.1; or SM 4500-NH3-G; or SM 4500-NH3-H	Colorimetric, phenate	10 µg/L
Total Kjeldahl Nitrogen	EPA 351.1; or EPA 351.2	Colorimetric, block digestion, phenate	50 µg/L
Total Suspended Solids	EPA 160.2; or SM 2540-D	Gravimetric	1 mg/L
Suspended Sediment Concentration	ASTM D3977	Gravimetric	1 mg/L
Turbidity	EPA 180.1; or SM 2130-B	Nephelometric	0.1 NTU
Electrical Conductivity	EPA 120.1; or SM 2510-B	Probe and sensor	1 µS/cm
pH	EPA 150.1; or SM 4500-H-B	Probe and sensor	0.01 SU
Particle Size Distribution	SM 2560; or RSWMP addendum SOP	Laser backscattering	NA

10.2 Sample Preservation and Holding Times

Chemical preservatives are often times added to water samples to prolong the stability of specific constituents during storage. The laboratory will first divide the submitted sample

into appropriate bottles for each analysis and then add the specific chemical preservative appropriate for each analysis. The use of preservatives is best left to analytical laboratory staff as the use of bottles pre-filled with preservatives increases logistical problems of the field crew.

Holding times represent the maximum time allowed from when the sample is taken to when the analytical laboratory performs the analysis or extraction. It is dependent both on the analytical method used and the specific analyte under consideration. For short holding times of 48 hours or less, water samples need to be collected and processed each day so they can be delivered to the laboratory for analysis as soon as possible. The laboratory should be notified before sampling begins so that it can prepare to preserve or analyze the samples upon delivery.

10.3 Laboratory Reporting

Laboratory results should be reported on a regular basis, and inquiries made if results are not delivered shortly after specified holding times. The analytic laboratory is expected to provide a complete results datasheet. Updates may occur if analyses with different holding times are staggered. The data transmission should always show the specific analytic methods used, corresponding reporting limits and a set of results from the QA/QC samples associated with those analytic run(s) performed.

The RSWMP Technical Unit will collect additional QA/QC information from each of the laboratories conducting RSWMP sample analyses, including any changes in method detection limits. These data will be collated and analyzed as part of the RSWMP QA/QC program. Results will be published in the annual interpretative reports.

11) Quality Assurance and Quality Control Procedures

The procedures used to collect, handle, and analyze water samples all contribute to the quality of analytical data. Acceptable data quality objectives (DQOs) should be developed prior to implementing the monitoring program. The quality of the data is assessed for contamination, accuracy, and precision using QA/QC procedures. Contamination is assessed using a variety of blank samples brought into or collected in the field to identify the source(s) of contamination. Accuracy is assessed for a given set of samples by comparing matrix or control spike samples against acceptable limits. Precision is assessed during data analysis by comparing analytical results for duplicate samples.

11.1 Field QA/QC Sample Types

Equipment blank: Collected once at the start of the sampling season, equipment blanks are used to assess if the sampling equipment itself is adversely affecting the quality of water samples. This ensures that the sample strainers and tubing can be replaced and the sampler cleaned prior to the first sampling event. Reagent-grade "blank" water is passed through the sampling equipment and collected. As with all blank samples, equipment blanks are submitted to the laboratory as "blind" samples, labeled as normal sample but with a false site name.

Travel blank: This blank is used to assess if sample contamination is introduced during sample transportation and delivery. Travel blanks are prepared in the laboratory by filling sample bottles with reagent-grade "blank" water. These samples are then transported to and from the sampling sites with the normal sample bottles. Submit trip blanks to the laboratory as blind samples.

Field blank: These samples are collected to identify sample contamination occurring during field collection, handling, transport, storage, and during laboratory handling and analysis. Field blanks are collected throughout the sampling season by pouring reagent-grade "blank" water into the autosampler bottles in the field and then exposing them to equivalent conditions as the standard sample bottles. Submit samples to the laboratory as blind samples.

Method (processing) blank: Prepared from clean laboratory-grade deionized water whenever sample processing (e.g. filtration, digestion) occurs, these are run with samples at the analytical laboratory. Method blanks are used to determine the level of contamination introduced by sample processing (different from analytic blanks).

Field duplicates: Two samples collected at the same time and treated identically are used to assess the reproducibility of collected data. This provides a measure of analytical precision and can be used for detecting problems in sample collection, handling, transport processing, and analysis. The actual procedures for collecting field duplicate samples depend on the sampling methods and protocols used. When automated sampling equipment is used, duplicates need to be collected manually either by: (a) triggering the sampler manually twice in quick succession; (b) manually triggering a sample and then collecting a grab sample at the same time, or; (c) manually triggering or collecting a grab sample immediately after or during a normally collected sample.

Laboratory duplicates and inter-laboratory splits: These samples are used to assess laboratory handling and the methods used for analytical measurements. These duplicates can be created at the processing stage and submitted to the laboratory with the same sample

identification but marked as duplicates. For inter-laboratory splits, two or more different analytical laboratories will each analyze the replicate samples. If their results differ by more than 20% then the methods used by each laboratory need to be compared and modified to ensure that their results remain comparable. If the replicate concentration is near detection limits, the project manager can waive the 20% criteria. The RSWMP Technical Unit will maintain an inter-laboratory QC program to assure consistent and comparable results by participating water quality analysis laboratories.

11.2 Laboratory QA/QC Sample Types

The following QA/QC procedures should be routinely run by the analytical laboratory as part of their Standard Operating Procedures (SOP), a copy of which should be included in the project's QAPP.

Matrix Spike: Spike samples are used to assess analyte recovery and data quality. This sample is created by adding a known amount of target analyte to an aliquot of a submitted water sample. Ideally the amount of analyte added to the matrix spike should be similar to the amount already in the sample so as not to overwhelm or be overwhelmed by the original amount. The results of the spike are compared against the unspiked sample to determine the percent recovery of the target analyte. If the spike is significantly more or significantly less than the concentration of analyte in the sample, it may not yield useful information. A blank spike should also be analyzed with each run to measure the ability of the laboratory and the method to recover that analyte in the absence of sample matrix. If recovery is good (within the designated recovery range for the analyte and method) for the blank spike, but poor (outside the recovery range) for the matrix spike, possible matrix interference in the sample should be reported.

Standard Reference Material (SRM) or Quality Control Sample (QCS): These are prepared by an external agency or derived from material different than used for calibration standards. The concentrations of analytes in the standards are certified within a given range of concentrations. These are used as an external check on laboratory accuracy. Concentrations determine for these materials should be within the method specific tolerances (generally ±10%) of the specified value.

Analytic replicate: An aliquot is split from a submitted water sample and analyzed as a duplicate.

Analytic blank: Run with each batch of samples, analytic blanks are used to determine if there is contamination or bleed-over between samples consecutively analyzed.

These are different from the method blanks, which indicate contamination introduced by sample processing (filtration, digestions, etc.)

11.3 QA/QC Sample Frequency

The minimum frequency of sample collection or preparation is shown in Table 4. The frequencies listed in this table may be increased depending on project objectives or if QA/QC problems, such as contamination of samples, are observed.

The collection of QA/QC samples should be staggered among sites and over time to maximize the coverage at all project sites. Therefore, the same type of QA/QC samples should not be collected from all sites during a given monitoring event. The sampling schedule should be reviewed periodically throughout the monitoring season to ensure that correct types and numbers of QA/QC samples are being collected, submitted and analyzed.

Table 4. Recommended QA/QC samples and frequency.

Sample Type	Sample Frequency	Description
Field duplicate	One per 5% of samples analyzed, or at least one per event, rotate sites	Collected as a manually triggered or grab sample immediately following a normal sample
Field blank	One per event per 10 sites, rotate sites	DI water deployed in standard field sample container during event or pre-event
Composite replicate	One per event per 10 sites, rotate sites	Processing and creation of a replicate composite sample at the laboratory
Method blank	One per 20 samples processed for each analyte, or one per run	DI water passed through standard laboratory sample processing procedure
Analytic replicate	At least one per run for each analyte, or 10% of samples	Split from sample added to analytic run
Analytic blank	One per run for each analyte	DI water passed through analytic procedure with samples
Matrix spikes	At least one per run for each analyte, or 10% of samples	Percentage recovery from spiked sample during analytic run
SRM or QCS	One per run for each analyte	Standard material from different source than calibration standards, analyzed with samples during analytic run
External audit samples	Once per year	These samples are obtained from the US EPA or other agencies with a QA/QC audit sample program
Internal audit samples (RSWMP)	Six samples per year (minimum)	These samples are prepared and distributed by the RSWMP Technical Unit.

Further information on laboratory QA/QC can be obtained from the respective DRI and UC Davis laboratory manuals (Thomas et al., 2008; Goldman et al. 2002), as well as

from other manuals, e.g. Standard Methods (APHA, 1992), the USGS (1985), and the EPA (1994).

11.4 Initial Screening of Laboratory Results

All data reported by the laboratory must be carefully reviewed to determine if there are any anomalies and if the project's data quality objectives (DQOs) have been satisfied. The project director or designee must immediately review this data for completeness and accuracy. All errors will be documented and corrected (where feasible) and the team and/or laboratory shall institute the appropriate corrective action necessary to improve data quality.

- ***Screen data for inadvertent errors.*** Conduct an initial screening that identifies and corrects documentation or process errors introduced by the field crew or laboratory. Compare chain of custody records with field logbooks and laboratory data to verify the accuracy of sample identification. Ensure that all samples have been submitted for analysis.
- ***Review sample representativeness and sample type***. Make sure that the minimum acceptable storm capture criteria have been met for composite samples. Verify that results for composite samples are not confused with those for individual samples.
- ***Check the laboratory data report for completeness***. Verify that the laboratory results include all samples submitted for each of the parameters requested. Make sure that the results of requested QA/QC samples (field blanks, field duplicates, etc.) and internal QA/QC laboratory results (if requested) are reported.
- ***Review the data for holding times and detection limits.*** The laboratory reports will be checked to verify that all analyses were performed within the prescribed holding times and that all reported analytical limits either meet or be lower than the levels agreed upon prior to laboratory submission.
- ***Review the data for reporting errors and apparent inconsistencies***. Identify laboratory results outside of the normally observed or expected range. Any suspect data must be verified with the laboratory. Examples include: (a) out-of-range values; (b) lack of agreement between laboratory duplicates or field duplicates; (c) higher than expected values reported for blanks, and; (d) inconsistent sample labeling. The laboratory may need to re-analyze and re-issue suspect results.

12) Data Management, Quality Evaluation, and Reporting

The quality of data needs to be periodically evaluated in order to provide checks that ensure that reported constituent concentrations in the water quality sample are accurate. This will often identify sources of contamination in and help to detect deficiencies in laboratory analyses and data reporting. Furthermore, temporal trends and project effectiveness calculations will unable to be calculated without a sufficient number of accurate data points.

12.1 Data Review

Evaluation and review will include: (a) contamination check results including method, field, trip and equipment blanks; (b) precision analysis results including laboratory, field, and matrix spike duplicates, and; (c) accuracy analysis results, including matrix spikes, laboratory control samples, and external reference standards.

Each of these QA/QC parameters will be compared to the data quality objectives determined prior to the start of the project. Key steps in this analysis include:

1. Compile all QA/QC results for each analyzed parameter
2. Evaluate laboratory QA/QC results against defined criteria
3. Compile and report out-of-range values to the laboratory for verification
4. Attach appropriate QA/QC qualifiers to data that do not meet defined criteria.
5. Tabulate the success rate for each QA/QC parameter analyzed.

Standard EPA guidelines should be applied for evaluating the results of contamination, accuracy, and precision checks and on qualifying data that do not meet data quality objectives (US EPA 1991 and 1994). Staff from the RSWMP Technical Unit will review data quarterly to determine whether the data quality objectives (DQOs) are being adequately met and suggest corrective action if necessary.

Data will be separated into three categories: (a) data meeting all data quality objectives; (b) data failing precision or recovery criteria, and; (c) data failing to meet accuracy criteria. Data meeting all data quality objectives, but failing to meet QA/QC criteria will removed from the dataset and re-evaluated later when the impact of the failure on data quality can be more fully determined. If sufficient evidence is found supporting data quality for use in this project, the data will be moved to the first category but will be flagged with a “J” as per EPA specifications.

12.2 Evaluation of Continuous Data Series

Continuous data measured at constant time intervals also needs to be assessed for their data quality. This data includes parameters measured in the field at a constant time interval, including stage, flow, turbidity, specific conductance, and water temperature. Data from continuous sensors may be erroneous for many reasons, including electrical interference, sensor removal during site visits, instantaneous spikes or peaks, sensor drift, sensor fouling and data transmission errors. Steps include the identification of erroneous data, assessing the need to apply a data correction, and then ranking the accuracy of the data based on field calibration checks.

Visual inspection of the data is conducted to assess the presence of anomalies and outliers that diverge from field calibration checks and from current data trends from other types of co-located sensors or with the same sensor type at appropriate nearby sites. Prior to project implementation, rules governing the correction of erroneous data must be developed, and should be consistent with common practices adopted by the USGS (Wagner et al., 2006).

Minimum and maximum allowable limits for data correction must be developed for every continuous parameter recorded. These limits are set based on project objectives and require a trade-off between the sensitivity of equipment used, the desired accuracy of the data set, and the time required for the dataset to be reviewed. Minimum limits are typically set near the readable precision of the device used for field calibration checks. Maximum allowable limits are typically set at 10 times greater the minimum level. Therefore, the continuous data will need to be corrected if the difference between the current logged reading and the calibration device exceeds the minimum allowable data correction limits and data must be redacted from the data set if it exceeds the maximum allowable data correction limit.

The following is an example of rules that can be adopted to correct erroneous data:

1. Missing or erroneous data due to known causes (e.g. during site maintenance):
    a. Will be interpolated if:
        i. missing or erroneous data was less than three consecutive hours in duration, and;
        ii. the trend (slope) of data during the hour preceding the questionable data is within 10% of that measured during the first hour after the questionable data.
    b. Will be removed from the data set if the duration of questionable data is longer than three consecutive hours or if the slope defined in 1.a.ii. exceeds 10% .

2. Correction of erroneous data due to sensor drift, fouling, or unknown origin:
    a. Will be conducted by interpolation if the erroneous data is:
        i. A single data point between two good data points, or;
        ii. Anomalous data consisting of two to three consecutive data points that exceed 2 times the criteria that result in a Poor quality ranking (described below).
    b. Will otherwise be corrected utilizing the constant or variable correction approach (described below).
3. If data correction results in a change that exceeds the maximum allowable limit (described below) then that data will be removed from the data set. This does not apply to situations where the data are known to have been linearly shifted, such as through the application of incorrect offset values.

Interpolation is the process where missing or erroneous data are corrected by linearly interpolating values based on known good points before and after the questionable data. The use of interpolation will be limited to a maximum of three consecutive hours and will only be applied if the corrected data remains consistent with similar data from nearby gauges. The constant correction approach entails adding an unchanging modifier to all questionable data in a given time period. This approach would be used, for example, to correct stage data if the calibration was misread, or the stage device was not properly retuned to its pre-calibration level. The variable correction approach uses a changing modifier to correct questionable data. This modifier normally starts at zero at the beginning of the time period and proportionally increases until it reaches its maximum value at the end of the time period. Variable corrections are typically used to correct for events that continue to aggregate through time, such as sensor drift and biofouling. If the start time of a variable correction cannot be specifically determined, the time of the last field calibration check will be used.

12.3 Data Management and Storage

Field personnel are responsible for recording and entering all data for this project. The project leaders will review these data and laboratory results to ensure accuracy and correctness. The data format, data entry, checking, and reporting protocols will follow the Tahoe RSWMP Database recommendations. Excel spreadsheets will be provided for database entry. Raw data will be backed up on CD-RW as acquired and all calculated data will be backed up to off-site servers weekly.

Raw data obtained from the sensors or data loggers should be maintained in original form, without any modifications. Analytic results are compiled for each site and maintained

in electronic worksheet form until uploading into the RSWMP Stormwater and BMP Performance Database. A copy of the data should be made for QA/QC modifications. All modifications to the data should, at the very least, be noted with a reason why the correction was applied and how the data were manipulated.

12.4 Data Reporting

All field measurements and observations will be recorded at the time of sampling. Samples collected in the field will be recorded on a standard chain of custody form for delivery to laboratories, as required. All data will be entered into Excel spreadsheets, developed for the Tahoe RSWMP Stormwater and BMP Performance Database.

Field and sampling personnel will be responsible for recording and entering all data for this project into the RSWMP Database. These data and laboratory results will be reviewed by the RSWMP Technical Unit to ensure accuracy and correctness. Outliers and anomalies will be identified using database protocols for detecting and correcting data entry and analysis errors.

13) References

Much of the material used in developing this document were adapted from existing information sources, including Heyvaert et al. (2009), Caltrans (2003), NDOT (2008), Geosyntec et al. (2009), Heyvaert and Reuter (2010) which are included in the references shown below.

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Appendix A. Example Description of Monitoring Location

Harold Drive Stormwater Site

The Harold Drive site is located on the southwest corner of Harold Drive and Village Blvd. in Incline Village, NV. Runoff collected at this site is primarily generated from Village Blvd. between Harold Drive to the south and prior to Peepsight Drive to the north (Figure A1). The area of contribution is 3.6 acres and with a slope of 7%. Although road runoff from Village Blvd. typically dominates stormwater collected at this site, other sources exist, including: runoff from College Blvd., mixed overland flow and urban runoff from the housing development on Golfer's Pass Road, and from driveways and smaller side streets on Village Blvd. to a lesser extent.

Washoe County applies traction control material to the intersection of Village Blvd. and College Drive prior to and during winter storm events. A street sweeper is used to remove traction control material remaining on the roadway within a few days of the street drying off.

Curb and gutters contain surface water along 2500 linear feet of Village Blvd. and deposit it into an underground stormwater conveyance system through 17 drop inlets (Figure A2). The conveyance system is comprised of a single mainline that follows the roadway with 6" diameter feeder pipes connecting to each of the drop inlets. The mainline is comprised of 18" diameter plastic pipe north of and 24" diameter plastic pipe south of College Blvd.

The monitoring site is located at the bottom of the mainline, prior to stormwater entering a CDS cyclonic stormwater treatment vault and then a detention basin. A 24" Palmer-Bolus flume and a pressure transducer are located in the vault's diversion/bypass flow antechamber. Data from a second pressure transducer located 6 feet up the mainline can be used to estimate flows that exceed the capacity of the flume. Water temperature and specific conductance are also measured. Sample lines and sensor cable are run to an equipment enclosure located just outside of the vault's effluent pipe.

An autosampler and data logging system are located within the enclosure. The data logger is programmed to trigger the autosampler and record sensor data. Data are collected on a 10-minute interval based on readings taken every 2 to 5 minutes, depending on the sensor type. When a sampling event has been initiated, the data logger also records data from the sensors on a 2-minute interval. Sampling events are initiated when stormwater flow through the flume meets a predefined level. The autosampler is triggered to collect water samples on a 30-minute interval once the minimum flow rate has been reached. Auxiliary sensors at this site also include air

temperature, barometric pressure, and rainfall. Telemetry is used to transmit the data back to DRI where it is available in graph and tabular form to field personnel via a website and is used to trigger automated emails to field staff when the autosampler is triggered or when data exceed preset thresholds.

Site directions: From the intersection of SR 28 (Lake Tahoe Blvd.) and SR 431 (Mount Rose Highway), head east on SR28 for 1.1 miles and turn north on Village Blvd. The site is 0.5 miles and on the east side of the road just before Harold Drive.

Site-specific maintenance: Coarse sediment is typically deposited at the bottom of the mainline just upstream of the flume due to the significant decrease prior to water entering the treatment vault. This sediment is removed with a wet/dry vac prior to storm events or designated snowmelt events. The mass of sediment is estimated and sampled for particle size distribution.

The site is located in a forested area with limited access to sunlight for solar power. Therefore, battery charge must be carefully monitored, particularly during multi-day sampling events having significant cloud cover. If the batteries are not adequately charging, they will be switched out with fully charged batteries and brought back to the lab for charging. When possible, sensors and equipment are turned off when not in use. For example, power to the telemetry system is only turned on for three hours a day during non-event time periods and for six hours a day during sampling events.

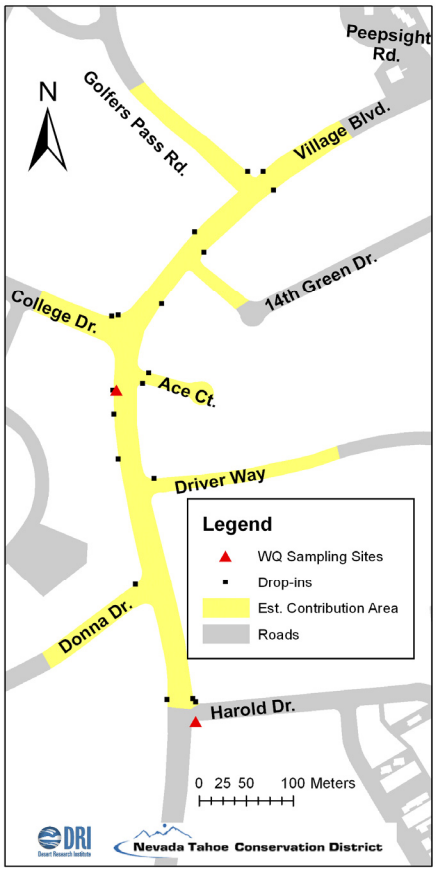

Figure A1. Map of the Harold Drive stormwater site.

Figure A2. One of the 17 drop inlets.

Figure A3. Looking southeast from corner of Harold Drive and Village Blvd., standing on the treatment vault. Water exits the vault and goes into a small detention basin (left). The equipment enclosure is being cleaned of snow (right). Photo courtesy of NTCD.

Appendix B. Particle Size Classification System, expressed in phi units as recommended by the American Geophysical Union (AGU).

Phi	Diameter (µm)	US Sieve	AGU Classification	Size Range (µm)
12	0.24	--	Colloids	<0.24
11.5	--	--	--	--
11	0.5	--	Very Fine Clay	0.24–0.50
10.5	--	--	--	--
10	1	--	Fine Clay	0.5–1.0
9.5	--	--	--	--
9	2	--	Medium Clay	1–2
8.5	--	--	--	--
8	4	--	Coarse Clay	2–4
7.5	--	--	--	--
7	8	--	Very Fine Silt	4–8
6.5	--	--	--	--
6	16	--	Fine Silt	8–16
5.5	--	--	--	--
5	31	--	Medium Silt	16–31
4.5	--	--	--	--
4	63	No. 230	Coarse Silt	31–63
3.5	--	--	--	--
3	125	No. 120	Very Fine Sand	63–125
2.5	--	--	--	--
2	250	No. 60	Fine Sand	125–250
1.5	--	--	--	--
1	500	No. 35	Medium Sand	250–500
0.5	--	--	--	--
0	1000	No. 18	Coarse Sand	500–1000
-0.5	--	--	--	--
-1	2000	No. 10	Very Coarse Sand	1000–2000
-1.5	--	--	--	--
-2	4000	No. 5	Very Fine Gravel	2000–4000
-2.5	--	--	--	--
-3	8000	5/16"	Fine Gravel	4000–8000
-3.5	--	--	--	--
-4	16,000	5/8"	Medium Gravel	8000–16,000
-4.5	--	--	--	--
-5	32,000	1-1/4"	Coarse Gravel	16,000–32,000
-5.5	--	--	--	--
-6	64,000	2-1/2"	Very Coarse Gravel	32,000–64,000

Appendix C. Example of Typical Chain of Custody (COC) Form

Water Analysis Laboratory
Desert Research Institute
2215 Raggio Parkway, Reno NV 89512
775-673-7380

CHAIN-OF-CUSTODY FORM

Project:		Analysis Requested						
Sample ID	Date Sampled							Comments

Relinquished by	Date and Time	Received by	Relinquished by	Date and Time	Received by
Relinquished by	Date and Time	Received by	Relinquished by	Date and Time	Received by