# Monitoring Protocol for Manufactured Treatment Devices

# Minnesota Pollution Control Agency

# June, 2022

# Home

**Acknowledgement and credit**

This document was developed using Washington State’s [Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies](https://apps.ecology.wa.gov/publications/documents/1810038.pdf), Technology Assessment Protocol – Ecology (TAPE), September 2018 revision of Publication no. 11-10-61, Publication no. 18-10-038. As appropriate, that document was modified for Minnesota stormwater runoff and climate conditions.

The document was reviewed by a technical work group. For a list of individuals on this group, [link here](https://stormwater.pca.state.mn.us/index.php?title=TP_and_TSS_credits_and_guidance_for_manufactured_treatment_devices_(mtds)#Technical_team_.28Acknowledgements.29).

Contents

[List of Tables 5](#_Toc101437921)

[Acronyms 6](#_Toc101437922)

[Introduction and Overview 7](#_Toc101437923)

[Preparing a Quality Assurance Project Plan (QAPP) 8](#_Toc101437924)

[Background 8](#_Toc101437925)

[Project description 9](#_Toc101437926)

[Organization and schedule 10](#_Toc101437927)

[Quality objectives 10](#_Toc101437928)

[Precision 11](#_Toc101437929)

[Bias 11](#_Toc101437930)

[Representativeness 11](#_Toc101437931)

[Completeness 13](#_Toc101437932)

[Comparability 13](#_Toc101437933)

[Experimental design 13](#_Toc101437934)

[Monitoring site 14](#_Toc101437935)

[Treatment system sizing 15](#_Toc101437936)

[Precipitation monitoring 15](#_Toc101437937)

[Flow monitoring 15](#_Toc101437938)

[Monitoring locations and equipment 16](#_Toc101437939)

[Water sampling 16](#_Toc101437940)

[Monitoring locations and equipment 16](#_Toc101437941)

[Sampling methodology 17](#_Toc101437942)

[Monitoring parameters 17](#_Toc101437943)

[Monitoring duration 18](#_Toc101437944)

[Sampling procedures 18](#_Toc101437945)

[Precipitation monitoring 19](#_Toc101437946)

[Flow monitoring 19](#_Toc101437947)

[Water sampling 19](#_Toc101437948)

[Sample preservation and handling 19](#_Toc101437949)

[Equipment decontamination 20](#_Toc101437950)

[Recordkeeping 20](#_Toc101437951)

[Measurement procedures 21](#_Toc101437952)

[Water sampling 21](#_Toc101437953)

[Quality control 23](#_Toc101437954)

[Field quality assurance and quality control 23](#_Toc101437955)

[Quality control samples 23](#_Toc101437956)

[Equipment maintenance and calibration 25](#_Toc101437957)

[Laboratory quality control 25](#_Toc101437958)

[Data management procedures 26](#_Toc101437959)

[Data verification and validation 26](#_Toc101437960)

[Data quality assessment 26](#_Toc101437961)

[Third-party review 27](#_Toc101437962)

[References 28](#_Toc101437963)

[Glossary 30](#_Toc101437964)

[Appendix A: Summary of modifications to TAPE protocol 39](#_Toc101437965)

[Appendix B: Preparing an addendum report 41](#_Toc101437966)

[General 41](#_Toc101437967)

[Organization and schedule 41](#_Toc101437968)

[Monitoring and site information 41](#_Toc101437969)

[Appendix C: Determining credits for manufactured treatment devices (mtds) 43](#_Toc101437970)

# List of Tables

Table 1. Example stormwater treatment mechanisms.

Table 2. Example measurement quality objectives for water quality monitoring.

Table 3. Storm event guidelines for monitoring.

Table 4. Sample collection requirements for automated, flow-proportional composite sampling.

Table 5. Required water quality parameters for monitoring.

Table 6. Example sample container, preservation, and holding times for water quality monitoring.

Table 7. Reporting limits and analytical methods for water quality parameters.

Table 8. Required particle size distribution size categories for the modified suspended sediment concentration method.

Table 9. Example quality control sample summary for water quality monitoring.

Table 10. Example equipment maintenance and calibration schedule.

# Acronyms

BMP Best management practices

CRM Certified reference materials

EMC Event mean concentration

GULD General use level designation

ISR Individual storm report

MQO Method quality objectives

MS Matrix spike

MSD Matrix spike duplicate

NPDES National Pollutant Discharge Elimination System

PE Performance evaluations

PSD Particle size distribution

QA Quality assurance

QA/QC Quality assurance/quality control QC Quality control

QAPP Quality Assurance Project Plan

RPD Relative percent difference

SSC Suspended sediment concentration

TAPE Technology Assessment Protocol-Ecology

TER Technical Evaluation Report

TP Total phosphorus

TSS Total suspended solids

# Introduction and Overview

Manufactured treatment devices (mtd) are pre-fabricated stormwater treatment structures utilizing [settling (sedimentation)](https://stormwater.pca.state.mn.us/index.php?title=Stormwater_sedimentation_Best_Management_Practices), [filtration](https://stormwater.pca.state.mn.us/index.php?title=Filtration), absorptive/adsorptive materials, vortex separation, vegetative components, and/or other appropriate technology to remove pollutants from stormwater runoff ([New Jersey Department of Environmental Protection](https://www.nj.gov/dep/dwq/highway/pdf/NJ_SWBMP_9.6.pdf)). Mtds may receive credit for removing total suspended solids (TSS), total phosphorus (TP), or total dissolved phosphorus (TDP) if appropriate monitoring protocols and conditions are met. Mtds receiving credit for removing total suspended solids (TSS) or total phosphorus (TP) must have received final general use level designation (GULD) certification through Washington State’s Technology Assessment Protocol – Ecology (TAPE) program for Basic treatment for TSS credit and Phosphorus treatment for total phosphorus.

Minnesota employs a tiered credit system for TP removal by mtds. These credits may be based on analysis of TAPE monitoring data. However, vendors, designers, manufacturers, and their consultants (all referred to herein as “proponents”) may wish to determine credits through additional monitoring. This document provides a protocol for preparing a Quality Assurance Project Plan (QAPP) for mtds undergoing water quality monitoring for purposes of determining pollutant removal credits in Minnesota, including **t**he required structure for QAPP submittals information required for QAPP submittals, monitoring site selection, monitoring program implementation, required monitoring methods, and experimental design components. This protocol is based on protocol developed for Washington State’s Technology Assessment Protocol-Ecology (TAPE) Program. The TAPE Program developed a technical guidance manual to assist proponents in monitoring site selection, QAPP development, and monitoring program implementation, all of which are required to certify stormwater treatment technologies in Washington State. Because of differences in runoff and climatic conditions between Washington and Minnesota, the Minnesota Pollution Control Agency (MPCA) Stormwater Program modified the TAPE protocol. Modifications to the TAPE protocol are displayed in yellow shading in this document. Appendix A summarizes modifications to TAPE protocol. Appendix B provides reporting requirements.

This protocol is specifically designed to evaluate flow-through mtds which have relatively short detention times. A proponent may request a preliminary meeting with the MPCA to discuss which portions of this technical guidance document apply to the technology they will be monitoring and to obtain input on other testing protocols that may be applicable. Vendors or manufacturers may prepare a QAPP and conduct their own field monitoring. However, an independent professional third party must verify that monitoring was conducted in accordance with this protocol and prepare a third-party review memorandum. Alternatively, a vendor or manufacturer may retain a third-party to prepare the QAPP and conduct field monitoring. This satisfies the third-party review requirement.

The proponent must submit a QAPP within 6 months of finding a suitable monitoring site and notifying MPCA. The proponent may submit the QAPP from the Washington State TAPE study used for GULD certification, with appropriate modifications as described in this document. The submittal must include the objective of the monitoring study (e.g., TSS credit, Tier 2 TP credit, or Tier 3 TP credit). If a Tier 3 TP credit is being sought, the submittal must include a description of the mechanism for achieving Tier 3 status (e.g., removal of dissolved phosphorus, volume retention, or demonstrated removal of TP greater than 60%). Appendix C summarizes crediting methodology for mtds.

Reviewers will be selected by the MPCA to provide technical review for the QAPP after its submittal. Based on recommendations of the reviewers, MPCA will either approve the QAPP or request modification of the QAPP from the proponent before the start of field monitoring. Proponents should allow up to 3 months for QAPP review and approval.

MPCA does not require removal of systems if field monitoring indicates that the technology did not perform as expected; however, the proponent is required to meet the terms of their agreement with the local jurisdiction or property owner.

If the mtd is part of a treatment train, the proponent must evaluate the performance of the mtd independent of treatment by other practices in the treatment train. The reviewers may evaluate factors other than treatment performance (e.g., site requirements, sizing methodology, installation, operation and maintenance requirements, reliability) to determine the appropriate uses (e.g., specific land use types, siting restrictions) of the stormwater treatment technology.

# Preparing a Quality Assurance Project Plan (QAPP)

**NOTE: The proponent may submit the QAPP from the TAPE study with a QAPP addendum. Appendix B describes the necessary components of a QAPP addendum.**

This section provides guidance on preparing the QAPP. The proponent must submit a QAPP that meets MPCA’s QAPP guidance and requirements within 6 months of finding a suitable monitoring site and notifying MPCA. The QAPP can be prepared by the vendor/manufacturer, an independent professional third party that will be conducting the monitoring program for the vendor/manufacturer, or another independent third party. QAPPs must include detailed information on the actual site that is selected for monitoring. Incomplete QAPPs will be returned to the proponent without review.

The required elements of a QAPP are described in the following sections. For information on QAPP preparation, see Washington State’s [Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies](https://apps.ecology.wa.gov/publications/documents/0403030.pdf), Publication No. 04-03-030 (Washington State Department of Ecology, 2004).

* Background
* Project description
* Organization and schedule
* Quality objectives
* Experimental design
* Sampling procedures
* Measurement procedures
* Quality control
* Data management procedures
* Audits and reports
* Data verification and validation
* Data quality assessment

# Background

The background section of the QAPP must provide a detailed description of the stormwater treatment technology sufficient to allow the reader to fully understand how the technology works. The Experimental Design section of the QAPP describes the specifics of the site selected for TAPE monitoring. The technology description in the QAPP must include the elements listed below at a minimum.

* Description of biological, chemical, or physical treatment mechanisms (see examples in Table 1)
* Design drawings and photographs
* Equipment dimensions
* Design hydraulic loading rate inches per hour (in/hr), cubic feet per second per square foot (cf3/s-ft2), gallons per minute per square foot ((gpm/ft2), cubic feet per second [cfs], inches per hour [in/hr])
* Explanation of site installation requirements
* Description of any pretreatment requirements or recommendations
* Description of any components of the treatment system that may contain phosphorus that might contribute to increased pollutant concentrations in the effluent
* Description of any components (i.e., concrete) that may result in pH fluctuations in the effluent
* Operation and maintenance requirements, including the anticipated frequency and duration of a typical maintenance cycle

**Table 1. Example stormwater treatment mechanisms.**

|  |  |
| --- | --- |
| **Treatment Category** | **Treatment Mechanisms a** |
| Biological | * Biological growth
* Denitrification
* Microbially mediated transformations
 | * Nitrification
* Plant uptake and storage
 |
| Chemical | * Absorption
* Adsorption
 | * Anion exchange
* Cation exchange
 |
| Physical | * Adhesion
* Adsorption
* Filtration
* Flocculation
* Impaction
 | * Interception
* Sedimentation
* Settling
* Straining
* Vortexing separation
 |

a This table provides examples of common biological, chemical, and physical treatment mechanisms that are present in stormwater treatment technologies. Additional treatment mechanisms not listed in this table may also be included.

# Project description

The QAPP should briefly describe the project, including the following information.

* Project objectives (i.e., characterizing pollutant removal effectiveness and effluent quality at the design hydraulic loading rate)
* Information (i.e., data) that will be required to meet the project objectives
* Number of test locations and approximate duration of monitoring
* Tasks that will be required to collect the data
* Potential constraints (i.e., seasonal or meteorological conditions, limited access, safety, or availability of personnel or equipment)

# Organization and schedule

The organization and schedule section of the QAPP must specify the following.

* Name, organization, and phone numbers of key members of the project team (i.e., project manager, test site owner/manager, field personnel, consultant oversight participants, and analytical laboratory contacts)
* Identification of who will perform the third-party evaluation
* Roles and responsibilities of the key members of the project team

Project schedule documenting when the treatment system and associated monitoring equipment will be installed, the expected field monitoring start date, and projected field sampling completion.

Proponents should allow up to 3 months for QAPP review and approval. It is also recommended that the proponent allow time for initial startup and testing of the treatment system and monitoring equipment at the beginning of the monitoring period.

# Quality objectives

The goal of the QAPP is to ensure that data collected during this study are scientifically and legally defensible. To meet this goal, the data must be evaluated using the following data quality indicators (Ecology 2004a):

* **Precision:** A measure of the variability in the results of replicate measurements due to random error. Random errors are always present because of normal variability in the many factors that affect measurement results. Precision can also be affected by the variations of the actual concentrations in the sample.
* **Bias:** The constant or systematic distortion of a measurement process, different from random error, which manifests itself as a persistent positive or negative deviation from the known or true value. This can result from improper data collection, poorly calibrated analytical or sampling equipment, or limitations or errors in analytical methods and techniques.
* **Representativeness:** The degree to which the data accurately describe the condition being evaluated, based on the selected sampling locations, sampling frequency and duration, and sampling methods.
* **Completeness:** The amount of valid data obtained from the measurement system.
* **Comparability:** A qualitative term that expresses the measure of confidence that one dataset can be compared to another and can be combined or contrasted for the decision(s) to be made. Data are comparable if sample collection techniques, measurement procedures, analytical methods, and reporting are equivalent for samples within a sample set and meet acceptance criteria between sample sets.

Measurement Quality Objectives (MQOs) are performance or acceptance criteria established for the data. The QAPP must specify MQOs that will be used in the assessment of water quality and hydrologic data, as described in the following subsections. The MQOs should be verified with the laboratory selected for sample analysis to confirm that they can be met.

## Precision

The QAPP must describe the measurement methodology and include the formula for calculating precision for both flow and water quality data. Relative percent difference (RPD) (i.e., the difference between two values divided by their mean and multiplied by 100) is the most frequently used MQO for the precision of duplicate laboratory or field samples. The QAPP must also include a MQO table indicating the acceptable percent recovery range for laboratory splits (laboratory duplicates) and MS/MSDs.

## Bias

The QAPP must describe the bias measurement methodology and include the bias calculation for both flow and water quality data. The QAPP must include a table listing each parameter, appropriate ranges for laboratory control limits, laboratory duplicate percent recovery ranges, matrix spike and matrix spike duplicate (MS/MSD) percent recovery ranges (if appropriate), and field duplicate percent recovery ranges (see Table 2 for an example). The proponent should describe precautions that will be taken to reduce bias due to sample collection procedures, sample transport, and sample storage (e.g., how samples will be kept cold during and after collection). Other bias sources, such as calibrations, reagent quality, method blanks, interference effects, dilutions, and field equipment contamination (equipment rinsate blanks) should also be discussed.

**Table 2. Example measurement quality objectives for water quality monitoring.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **Laboratory Control Sample (LCS) Recovery** | **Laboratory Duplicate RPD** | **Matrix Spike (MS) Recovery** | **Matrix Spike Duplicate (MSD) RPD** | **Field Duplicate RPD** |
| TSS | 80 – 120% | ≤20% | NA | NA | ≤20% |
| PSD | NA | ≤20% | NA | NA | ≤20% |
| pH a | NA | NA | NA | NA | ≤10% |
| TP | 80 – 120% | ≤20% | 75 – 125% | ≤20% | ≤20% |
| TDP | 80 – 120% | ≤20% | 75 – 125% | ≤20% | ≤20% |
| Orthophosphate | 80 – 120% | ≤20% | 75 – 125% | ≤20% | ≤20% |

NA – not applicable

RPD – relative percent difference

TP – total phosphorus

TDP – total dissolved phosphorus

TSS – total suspended solids

a pH is measured in the field and accuracy is ensured by calibrating the instrument before and after each use.

## Representativeness

Sampling events should be selected to represent a range of conditions with respect to rainfall volume and intensity to ensure the representativeness of the data. Storm event guidelines listed in Table 3 should be used to define the acceptability of specific storm events for sampling and assist with evaluating water quality monitoring data obtained from monitoring. Samples must be collected over one full calendar year.

The QAPP must also describe the measures taken to ensure that collected samples represent a wide range of water quality conditions during storm flow conditions, including criteria for minimum aliquot numbers and storm event hydrograph coverage. These guidelines help to ensure that flow-proportional composite samples are representative of an event-mean concentration (EMC). Table 4 presents requirements to ensure that flow-proportional composite samples are representative of the EMC of targeted storm events.

**Table 3. Storm event guidelines for monitoring.**

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Definition** | **Guideline a** |
| Minimum storm depth | Total rainfall amount during the storm event | 10th percentile one-year storm eventb |
| Storm start (antecedent dry-period) | Defines the storm event’s beginning as designated by minimum time interval without significant rainfall | 12 hours minimum with less than 0.04 inches of rain |
| Storm end (post storm dry period) | Defines the storm event’s end as designated by minimum time interval without significant rainfall | 12 hours minimum with less than 0.04 inches of rain |
| Average storm intensity | Total rainfall amount divided by total rainfall duration (e.g., inches per hour) | Range of rainfall intensities c |

a Provide justification in the Addendum (see Appendix B) for storm event data that do not meet the storm event guidelines, but are included in the data analysis.

b The 10th percentile event can be interpreted [from information on this page](https://stormwater.pca.state.mn.us/index.php?title=Rainfall_volume-frequency_maps), or you may use the following information based on proximity to your site: Minneapolis/St. Paul – 0.28 inches, Fargo – 0.21 inches, Lamberton – 0.22 inches, St. Cloud – 0.24 inches, Grand Marais – 0.24 inches, Itasca – 0.22 inches, Rochester – 0.26 inches.

c To assess performance on an annual average basis and performance at the system’s peak design rate, proponents should collect samples over a range of rainfall intensities.

**Table 4. Sample collection requirements for automated, flow-proportional composite sampling.**

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Definition** | **Requirement** |
| Minimum aliquot number | The number of equal-volume samples collected during a storm event that are combined to create a composite sample | 10 aliquots |
| Storm event coverage | The percentage of the total storm volume that the collected aliquots represent | For storm events lasting less than 24 hours, samples shall be collected for at least 75% of the storm event hydrograph (by volume). |
| Maximum sampling duration | Time in hours between collection of the first and last aliquots | 24 hours |
| Minimum number of samples | Number of storm events with successfully collected flow- proportional composite samples meeting influent concentration ranges and the storm event guidelines | 15 samples |

Finally, the representativeness of the hydrologic data for the flow monitoring should also be addressed by the proper installation of the monitoring equipment.

## Completeness

Completeness for water sampling can be calculated by dividing the number of valid values by the total number of values. Completeness can be defined in terms of the number or percentage of valid measurement needed to meet the project’s objectives (Ecology 2004a). Valid sample data consists of unflagged data and estimated data that has been assigned an estimated value (*J*) qualifier but deemed usable. *J* qualified data indicate the parameter was detected above the reported quantitation limit; however, the associated concentration is considered an estimate due to a quality assurance issue. A qualitative assessment must be made as to which *J* flagged data may need to be excluded from this calculation before the production of the final report. The rationale for acceptance of *J* flagged data must be documented.

A minimum of 12 valid flow-proportional composite samples meeting the specified influent concentration ranges are required to evaluate the performance of the system. The storm event guidelines identified in Table 3 should also be evaluated to assess the validity of the samples collected.

Completeness for flow monitoring must be assessed based on the occurrence of gaps in the data record. Gaps include data that are known to be inaccurate and cannot be corrected using available calibration data. The associated MQO must identify the maximum percentage of the data record during storms and over the entire monitoring period that can be missing and still meet the goals for flow monitoring specified in the QAPP. Completeness will also be ensured through routine maintenance of all monitoring equipment and the immediate implementation of corrective actions if problems arise.

## Comparability

There is no numeric MQO for this data quality indicator; however, standard sampling procedures, analytical methods, units of measurement, and reporting limits applied during TAPE monitoring will address the goal of data comparability. The results should be tabulated in standard spreadsheets to facilitate analysis and comparison with performance data from other stormwater treatment technologies.

# Experimental design

As described above, performance of a stormwater treatment technology must be demonstrated based on field testing performed under rainfall conditions described in Table 3. This testing will involve continuous flow and precipitation monitoring, the collection of water quality samples during discrete storm events, and accumulated sediment sampling. The QAPP must provide detailed information on the following experimental design elements for this testing.

* Monitoring site
* Treatment system sizing
* Precipitation monitoring
* Flow monitoring
* Water sampling
* Sediment sampling

The following sections provide guidance on each of these elements.

## Monitoring site

Proponents must conduct field monitoring at a one site. Pooling data from multiple sites is not allowed. The proponent is responsible for the cost of completing this evaluation, including laboratory testing and field monitoring. MPCA recognizes the need to minimize the cost of monitoring. To the extent applicable, the following list provides ways to minimize cost yet provide sufficient verification data.

* Conduct field reconnaissance to confirm suitability of site for monitoring based on predominant land use, drainage system configuration, and property access.
* Select sites with simple hydraulics to avoid compromising flow or water quality data.
* Avoid sites with steep slopes, junctions, confluences, grade changes, and areas of irregular channel shape due to breaks, repairs, roots, and debris.
* Avoid sites affected by high groundwater levels.
* Collect grab samples and analyze for total suspended solids (TSS), particle size distribution (PSD), and other key parameters (e.g., phosphorus) to evaluate potential field monitoring sites, verify that influent concentrations will fall within the acceptable influent ranges, ensure a representative site, and size the treatment system.
* Periodically evaluate the results to check for statistical significance and acceptability.
* Use laboratory testing to supplement field monitoring results for high flow rates that may be difficult to obtain during field monitoring.

Monitoring sites should be selected to be consistent with the technology’s intended applications and geographic location. Monitoring sites must provide influent concentrations typical of stormwater for those land use types. The following information about the monitoring site must be included in the QAPP, if applicable.

* Drainage area contributing to the treatment system, land use (e.g., roadway, commercial, high-use site, residential, industrial), percentage of drainage area that is impervious, and percentage of drainage area that is pervious. A description of the types of vegetation present in the drainage area should also be included.
* Description of potential pollutant sources in the drainage area (e.g., parking lots, roofs, landscaped areas, sediment sources, exterior storage, or process areas).
* Baseline stormwater quality information to characterize conditions at the site. For sites that have already been developed, it is recommended that the proponent collect baseline data to determine whether site conditions and runoff quality are conducive to performance monitoring.
* Vicinity map showing site location, drainage area, impervious area, slopes, existing drainage system, and other important hydrologic information.
* Site schematic in plan and profile showing treatment system and monitoring equipment locations.
* Latitude and longitude of the treatment system.
* Make, model, hydraulic loading rate, and design flow (maximum treatment flow rate; gpm) of the treatment system.
* Location and description of the closest receiving water body.
* Description of bypass flow rates or flow splitter designs necessary to accommodate the treatment facility.
* Description of pretreatment system, if required by site conditions or treatment system operation.
* Description of any known adverse site conditions such as climate, high groundwater, rainfall pattern, steep slopes, erosion, high spill potential, illicit connections to stormwater drainage system, or industrial runoff.
* Photo documentation of site conditions.

## Treatment system sizing

Minnesota does not require an mtd to meet a specific performance goal. Sizing of an mtd for the designed hydraulic loading rate must be reported in the QAPP or QAPP Addendum (see Appendix B). Acceptable methods for sizing a device are [discussed in the Minnesota Stormwater Manual.](https://stormwater.pca.state.mn.us/index.php?title=TP_and_TSS_credits_and_guidance_for_manufactured_treatment_devices_(mtds)#Calculating_annual_volume_treated)

## Precipitation monitoring

This section of the QAPP must describe the monitoring location and equipment selected for precipitation monitoring. Rainfall monitoring must be performed within the treatment system drainage basin or adjacent to monitoring equipment installed for the project. The actual rain gauge for this monitoring must be sited appropriately (e.g., away from large trees, out of the rain shadow of an adjacent building) to ensure accurate measurements. Rainfall monitoring must be performed to measure and record rainfall continuously throughout the monitoring period at 15-minute intervals or less, with 5 minutes preferred. The QAPP must indicate the type of rain gauge used (e.g., an automatic recording electronic rain gauge, such as a tipping bucket connected to a data logger, that records rainfall in 0.01-inch increments) and make and model number of the selected rain gauge. The rain gauge location must be shown on the site schematic if it is located at the monitoring site or on the vicinity map if it is in another portion of the drainage basin.

If the onsite rainfall monitoring equipment fails during a storm event, the proponent should use data from the next closest, representative monitoring station to determine whether the storm event meets the defined storm guidelines. Nearby third-party rain gauges may be used only in the event of individual rain gauge failure and only for the period of failure. The location of third-party rain gauges that will be used for this purpose should be identified in the QAPP. If third-party rain gauges are used to fill in data gaps, the proponent will be required to establish a regression relationship for individual storm events between the site and third-party rain gauges and use the regression equation to adjust the third-party data to represent site rainfall when needed.

## Flow monitoring

This section of the QAPP must describe monitoring locations and equipment selected for flow monitoring. This section must also include guidelines used to ensure that the flow monitoring experimental design is representative, comparable, and complete.

## Monitoring locations and equipment

Effluent and bypass flow rates must be measured continuously throughout the monitoring period. Influent flow is calculated in real-time as the sum of treated effluent and bypass flow. For offline systems or those with bypasses, flow must be measured at the bypass as well as at the outlet. For offline flow, the proponent must describe the type of flow splitter that will be used and specify the bypass flow set point.

The following requirements apply when selecting specific locations for flow monitoring:

* **Effluent:** Measure flow as close as possible to the treatment system outlet to ensure that the depth and flow measurements represent the water leaving the treatment system. Do not measure effluent flow in areas of the conveyance system that are mixed with bypass flows.
* **Bypass:** The proponent must measure all bypass flows. Do not measure bypass flows in areas of the conveyance system that are mixed with effluent flow.
* **Influent (optional):** If influent is measure, measure flow as close as possible to the treatment system inlet to ensure that the depth and flow measurements represent the water that enters the system. The influent flow should be measured in or adjacent to the treatment system.

The QAPP must also identify site conditions (e.g., high groundwater levels) that could affect flow measurement accuracy. Provide a description of how backwater conditions will be avoided (e.g. with velocity sensors). All flow measurement equipment should be installed in locations that can be accessed easily and safely. Because this equipment requires frequent calibration and maintenance, it must be directly accessible over the course of the monitoring.

Flow monitoring equipment must be selected to continuously measure and record flow into and out of the treatment system over the entire monitoring period. Flow must be logged at a 5-minute or shorter interval, depending on site conditions. The appropriate flow measurement method depends on the nature of the monitoring site and the stormwater drainage system. Depth measurement devices and velocity measurement devices are commonly used types of flow measurement equipment. The QAPP should identify the make and model number of the selected flow monitoring equipment. Additionally, the flow monitoring equipment locations must be identified in the QAPP on the site schematic in plan and profile.

# Water sampling

This section of the QAPP must describe monitoring locations and equipment, sampling methodology, monitoring parameters, and the monitoring duration for water sampling. This section must also include guidelines used to ensure that the water sampling experimental design is representative, comparable, and complete.

## Monitoring locations and equipment

To accurately measure system performance, water quality samples must be collected from both the inlet and outlet of each treatment system. The proponent is not required to measure water quality parameters in the bypass flow. Automated samplers should be used for sample collection, except for chemical constituents that require manual grab samples (e.g., TPH) or field meters (e.g., pH). Tygon or Teflon tubing may be used for sampling conventional parameters and metals. The QAPP should also identify the make and model number of the selected automated sampling equipment and the pH field meter. Additionally, the automated sampler locations must be identified in the QAPP on the site schematic.

When selecting monitoring locations, the proponent should be aware that settleable or floating solids, and their related bound pollutants, may become stratified across the flow column in the absence of adequate mixing. Influent and effluent samples must be collected at a location where t he stormwater flow is well-mixed. The following requirements apply when selecting specific locations for water sampling:

* **Influent:** Collect samples as close as possible to the treatment system inlet to ensure that the samples represent the water that enters the system. The influent must be sampled at a location unaffected by accumulated or stored pollutants. The sampling location should be located an appropriate distance from the flow monitoring equipment to avoid skewing depth and flow measurements when the automated sampler pump is operating.
* **Effluent:** Collect samples as close as possible to the treatment system outlet to ensure that the samples represent the treated effluent. Do not sample in areas of the conveyance system that mix with bypass flows. The sampling location should be located an appropriate distance from the flow monitoring equipment to avoid skewing depth and flow measurements when the automated sampler pump is operating.

The rationale for selecting specific sampling locations must be documented in the QAPP.

## Sampling methodology

Automated sampler programming must be included in the QAPP. Proponents should refer to the *Standard Operating Procedure for Automatic Sampling for Stormwater Monitoring* (Ecology 2009a) and the *Standard Operating Procedure for Collecting Grab Samples from Stormwater Discharges* (Ecology 2009b) when developing this section of the QAPP. Washington State’s Ecology has identified the following four sampling methods for evaluating emerging stormwater treatment technologies. Sampling methods 1 and 4 are required for all monitoring programs. Sampling method 2 may be required to evaluate pollutant removal as a function of flow rate; however, these same data may be obtained in a laboratory setting. Sampling method 3 is not commonly used but can be an alternative method to combine sampling methods 1 and 2.

Influent concentration ranges are specified below

* TSS: 20-200 mg/L
* TP: 0.10-0.80 mg/L
* TDP: 0.05-0.50 mg/L
1. **Automated flow-proportional composite sampling:** Using this method, the proponent will use an automated sampler to collect samples over the storm-event duration and composite them in proportion to flow. This sampling method is required for all monitoring programs to generate EMCs that will be used to determine whether the treatment system meets performance goals. Sample collection requirements specified in Table 4 must be met to generate a valid sample. The storm event guidelines identified in Table 3 should also be evaluated to assess the validity of collected samples. This method is appropriate for short detention flow-through systems where effluent flows are controlled by the function of the treatment system. Laboratory testing cannot be used to replace automated flow-proportional composite sampling.
2. **In situ sampling**: This sampling method is required for all monitoring programs. pH measurements should be collected *in situ* using a field meter.

## Monitoring parameters

The QAPP must identify the required water quality parameters to be monitored from Table 5. The proponent must tailor the sampling regime to support the desired treatment level (basic or phosphorus). The performance claims may be evaluated in relation to one or more of the parameters listed in the tables below. Proponents must analyze applicable parameters listed in Table 5 at both the inlet and outlet sampling stations.

**Table 5. Required water quality parameters for monitoring.**

|  |  |  |
| --- | --- | --- |
| **Performance Goal** | **Required Parameters** | **Required Screening Parameters a** |
| Basic | TSS | PSD, pH b |
| Phosphorus | TSS, TP, total dissolved phosphorus, orthophosphate | PSD, pH b |

a Screening parameters are required to be analyzed on three of the composite samples (or three *in situ* samples for pH) collected during the monitoring period (preferably spread throughout the monitoring period, with one sample collected towards the beginning, one in the middle, and one towards the end). Proponents may also choose to analyze the screening parameters for additional storm events.

b *In situ* sample only. If a substantial change in pH is measured (> 1 standard unit difference between influent and effluent measurements) or an abnormal pH value is measured (< 4 or > 9 standard units), additional storm events must be monitored.

PSD – particle size distribution

TP – total phosphorus

TSS – total suspended solids

Required screening parameters must also be collected from all treatment systems during three storm events during the monitoring period (preferably spread throughout the monitoring period, with one sample collected towards the beginning, one in the middle, and one toward the end) to determine if the treatment system could potentially export phosphorus or cause a change in pH. The results from the screening parameter analysis will be used to determine if pH adjustment is a necessary component of the treatment system. PSD analysis is also listed as a required screening parameter to determine if the influent PSD to the treatment system consists primarily of silt-sized particles (i.e., 3.9 to 62.5 microns) and thus is representative of stormwater. PSD data can also provide information regarding solids transport during a storm.

## Monitoring duration

As indicated in Table 4, a minimum of 15 flow-proportional composite samples must be collected over a minimum one-year calendar period to ensure representative concentrations are available for assessing system performance across a variety of storm event conditions. However, there is no maximum number of samples specified under this protocol. Rather, sampling must continue until enough samples have been collected to demonstrate performance of the system at the required level of statistical confidence [described in the Minnesota Stormwater Manual](https://stormwater.pca.state.mn.us/index.php?title=TP_and_TSS_credits_and_guidance_for_manufactured_treatment_devices_(mtds)#TP_and_TSS_credits). In all cases, samples must fall within the influent concentration ranges specified below and meet the sample collection requirements specified in Table 4 for flow-proportional composite samples. The storm event guidelines identified in Table 3 should also be evaluated to assess the validity of collected samples.

Influent concentration ranges are specified below

* TSS: 20-200 mg/L
* TP: 0.10-0.80 mg/L
* TDP: 0.05-0.50 mg/L

# Sampling procedures

This section of the QAPP describes field sampling procedures necessary to ensure the quality and representativeness of the collected samples. This section includes information on precipitation monitoring, flow monitoring, water sampling, and sediment sampling.

## Precipitation monitoring

The proponent must install and calibrate the rain gauge in accordance with manufacturer’s instructions, inspect the rain gauge monthly (at a minimum), and perform maintenance on the rain gauge (if necessary). Rain gauge calibration should be checked upon installation and once annually (at a minimum). This section of the QAPP should describe the specific steps that will be performed during these activities.

## Flow monitoring

The proponent must install and calibrate monitoring equipment in accordance with manufacturer’s instructions, inspect equipment after each sampled storm event (at a minimum), and perform maintenance on the equipment (if necessary). This section of the QAPP should discuss the specific measures taken during pre-storm visits to remove blockages from the conveyance system, check the operational status of the flow monitoring equipment, and calibrate sensors installed at the inlet, outlet, and bypass monitoring stations. Flow monitoring equipment calibration should be checked upon installation and monthly throughout the monitoring period (at a minimum). Control charts and other quality assurance measures should be used to track instrument drift. Control limits (statistical warning and action limits calculated based on control charts) should be established to track instrument drift. Warning limits are generally set at

±2 standard deviations from the mean and action limits at ±3 standard deviations from the mean. Flumes or weirs used in conjunction with flow monitoring may not match factory specification, become distorted during installation, be installed incorrectly, or settle unevenly over time; all of which will affect flow measurements. Dynamic *in-situ* flow calibration is recommended to address these issues.

## Water sampling

This section of the QAPP must discuss equipment decontamination, sample preservation and handling, and recordkeeping.

### Sample preservation and handling

Proponents should preserve samples in accordance with U.S. EPA-approved methods (U.S. EPA 1983) or Standard Methods (APHA, AWWA, WEF 2005). For composite samples that will be split into separate aliquots for preservation and/or analysis, maintain the sample at ≤ 6 degrees Celsius (°C) until collection, splitting, and preservation is completed (40 CFR 136.3). Holding times before and after sample preservation and filtration should be observed and must be recorded. Automated samplers must be filled with ice or refrigerated to maintain low temperatures throughout the sample collection period. The chain-of-custody form for composite samples must include the date and time of the last aliquot collection and the date and time of filtration or preservation (if applicable). The analytical laboratory needs this information to determine if a holding time has been exceeded.

Samples of dissolved phosphorus and orthophosphate (PO4) shall be filtered with a disposable 0.45 μm glass fiber filter at the laboratory prior to analysis. If laboratory analyses cannot be accomplished within the applicable hold time, the respective samples shall be preserved through freezing of the sample at the

laboratory. If preservation through freezing cannot be accomplished, the sample will be discarded.

The proponent may collect and submit for analysis samples filtered in the field **in addition to** samples filtered in the laboratory. Field-filtered samples of dissolved phosphorus and orthophosphate (PO4) shall be filtered with a disposable 0.45 μm glass fiber filter. In-line filtration is preferred, but hand-pumped filtration (e.g. for composite samples) is acceptable. The MPCA will evaluate both laboratory- and field-filtered samples in its analysis.

The QAPP must include a table listing analytical container material, minimum required sample volume, sample preservation requirements, and pre- and post-preservation holding time limits for the analyzed pollutants (see example in Table 6). The minimum required sample volume can vary based on the laboratory, methodology, and sampling configuration selected, thus it is not included in Table 6. Additional sample volume may be required for laboratory quality assurance and quality control (QA/QC) samples. Proponents should check with their selected laboratory to determine the minimum required sample volume for each parameter to be analyzed and list this volume in the QAPP. Proponents should obtain pre-cleaned sample bottles directly from the analytical laboratory. If the proponent proposes to obtain bottles from another source, a detailed bottle cleaning procedure must be provided in the QAPP. The QAPP must also describe procedures that will be employed to label and track samples from collection through delivery to the analytical laboratory and include a sample chain-of-custody form.

### Equipment decontamination

The QAPP must describe how water sampling equipment (sampler head and suction tubing) and will be decontaminated between sampling events and how frequently the suction tubing will be replaced to prevent contamination. It is recommended that the tubing be replaced at least once during the monitoring period and more frequently for highly contaminated runoff.

## Recordkeeping

The QAPP must also include a standardized field form that will be used for the project to record any relevant information noted at the collection time or during site visits. The field form should include at least the following information:

* Date and time
* Field staff names
* Weather conditions
* Number of samples collected
* Sample description and label information
* Field measurements
* Field QC sample identification
* Sampling equipment condition
* Instrument calibration procedures
* Measurements of sediment accumulation

The field form should also include space for notations about activities or issues that could affect the sample quality (e.g., sample integrity, test site alterations, maintenance activities, improperly functioning equipment, construction activities, reported spills, and other pollutant sources).

**Table 6. Example sample container, preservation, and holding times for water quality monitoring.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Sample Container** | **Preservative a** | **Pre-filtration Holding Time** | **Total Holding Time** |
| TSS | P, FP, G | Cool, ≤6°C | NA | 7 days |
| PSD | P, FP, G | Cool, ≤6°C | NA | 7 days |
| pH | NA | NA | NA | NA |
| TP | P, FP, G | Cool, ≤6°C; H2SO4 to pH < 2 | NA | 28 days |
| Total dissolved phosphorus and Orthophosphate | P, FP, G | Cool, ≤6°C; filtration, 0.45 µm | 12 hours b | 48 hours |

Source: Ecology (1997, 2004a) and 40 CFR 136.3, Table II

a For composite samples that will be split into separate aliquots for preservation and/or analysis, maintain the sample at ≤ 6°C until collection, splitting, and preservation is completed (40 CFR 136.3).

b Pre-filtration holding times of 15 minutes for orthophosphate is recommended in U.S. EPA (1983) and required in 40 CFR 136.3, Table II; however, these holding times cannot be realistically met with flow proportional automated sampling techniques. Consequently, a surrogate holding time of 12 hours from the time that the last aliquot was collected can be used for this monitoring. MPCA will accept data qualified as an estimate (*J*) if filtration (at the laboratory or in the field) occurred between 15 minutes and 12 hours after the last aliquot was collected.

FP – fluoropolymer (polytetrafluoroethylene [PTFE, Teflon] or other fluoropolymer)

G – glass

H2SO4 – sulfuric acid

NA – not applicable

P – polyethylene

PSD – particle size distribution

 TP – total phosphorus

TSS – total suspended solids

# Measurement procedures

This section of the QAPP focuses on laboratory procedures for water and sediment analysis. Laboratories must be certified by a national or state agency that regulates laboratory certification or accreditation programs. For test sites located in the state of Minnesota, proponents must complete all laboratory work at a Minnesota Department of Health accredited laboratory. For a list of accredited laboratories, see: <https://eldo.web.health.state.mn.us/public/accreditedlabs/labsearch.seam>.

## Water sampling

A table (see example in Table 7) must be provided in the QAPP that includes the following information:

* Parameter
* Sample matrix (water)
* Analytical method (include preparation procedures as well as specific methods especially when multiple options are listed in a method)
* Reporting limits for each given analytical method (include the associated units)

Reports obtained from the laboratory must include the sampling date, the preservation date (if applicable), the filtration date (if applicable), the extraction date, the analysis date, and indicate if the sample is a QC sample.

The recommended PSD analysis method is a modified *Suspended Sediment Concentration (SSC) Method* according to American Society for Testing and Materials (ASTM) Method D3977-97 (ASTM 2002) using wet sieve filtration (Method C) and glass fiber filtration (Method B). The SSC method uses wet sieve filtration (Method C) to measure the sand concentration by passing the entire sample (minimum volume of 1 liter) through a 62.5-micron (No. 230) sieve and uses glass fiber filtration (Method B) to measure the fines (silt/clay) concentration by passing the wet sieve filtrate through a 1.5-micron glass fiber filter. A modification of this procedure is recommended to measure the concentration of two sand fractions: very fine to fine sand between 62.5 and 250 microns, and medium to coarse sand greater than 250 microns (No. 60 sieve). The required PSD size fractions and their associated sieve sizes are summarized in Table 8.

**Table 7. Reporting limits and analytical methods for water quality parameters.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Category** | **Parameter** | **Method (in water)** | **Reporting Limit Target a,b** |
| Conventional | TSS PSDpH | SM 2540B c or SM 2540D cModified SSC method (based on ASTM Method D3977-97)EPA Method 150.2 | 1.0 mg/L NA0.2 units |
| Nutrients | TPTotal dissolved phosphorus and Orthophosphate(after filtering) | EPA Method 365.3. EPA Method 365.4, SM 4500-P E, or SM 4500-P FEPA Method 365.3. EPA Method 365.1, SM 4500-P E, or SM 4500-P F | 0.01 mg/L0.01 mg/L |

a Reporting limit targets established as per the Phase I Municipal Stormwater Permit (Ecology 2007). To the extent possible, reporting limits for the laboratory selected by the proponent should be the same or below those given in the table.

b All results below reporting limits should also be reported and identified as such. These results may be used in the statistical evaluations.

c To ensure accurate results, Ecology recommends modifying these methods to analyze (filter) the entire field sample. Research indicates that errors may be introduced by decanting a subsample, although using a funnel splitter may help. The analyst may also consider analyzing several premixed subsamples from the sample container to determine if significant variability occurred due to stratification. Reports shall indicate whether the entire field sample or a subsample was analyzed.

PSD – particle size distribution

SM – Standard Methods

 TP – total phosphorus

TSS – total suspended solids

mg/L – milligrams per liter

**Table 8. Required particle size distribution size categories for the modified suspended sediment concentration method.**

|  |  |  |
| --- | --- | --- |
| **Size Category (µm) a,b** | **Particle Description** | **Analysis Method c** |
| > 500 | Greater than medium sand | Retained on No. 35 sieve |
| 250 - 500 | Medium sand | Passing No. 35 sieve and retained on No. 60 sieve |
| 125-250 | Fine sand | Passing No. 60 sieve and retained on No. 125 sieve |
| 62.5 - 125 | Very fine sand | Passing No. 125 sieve and retained on No. 230 sieve |
| 4 – 62.5 | Silt | Passing No. 230 sieve and retained on No. 325 sieve |
| < 4 | Clay and colloidal | Passing No. 325 sieve |

a Size categories based on the Wentworth (1922) grade scale.

b Additional size categories may be added to the analysis if the proponent would like to acquire additional particle size distribution data.

c Sieve sizes based on ASTM standard sieve sizes

µm – microns

Further modification of the SSC method is allowed if additional size fractions are desired by the

proponent for evaluating effects of particle size on pollutant removal. Analysis of additional sand fractions may be conducted by using two additional sieves (No. 125 and 500 microns) in the wet sieve filtration to differentiate between very fine and fine sand (125 microns, No. 120 sieve) and between medium and coarse sand (500 microns, No. 35 sieve). Analysis of the silt and clay fractions may also be conducted by laser diffraction to determine the percentages of coarse silt (62.5-31.25 microns), medium silt (31.25-15.6 microns), fine silt (15.6-7.8 microns), very fine silt (7.8-3.9 microns), and clay (<3.9 microns). These size categories are based on the Wentworth (1922) grade scale.

# Quality control

This section of the QAPP includes information on field QA/QC and laboratory quality control.

## Field quality assurance and quality control

The field QA/QC section of the QAPP must describe the measures that the proponent will employ to ensure the representativeness, comparability, and quality of field samples. Field QA/QC must include the following elements:

* Quality control (QC) samples
* Equipment maintenance and calibration
* Equipment decontamination (see *Sampling Procedures*)
* Sample preservation and handling (see *Sampling Procedures*)
* Recordkeeping (see *Sampling Procedures*)

## Quality control samples

The field QC samples that should be collected by the proponent include equipment rinsate blanks and field duplicate samples. The QAPP must also include a table specifying the frequency and type of quality control to be performed with each batch of samples to be analyzed (see example in Table 9). Additional field QC samples (e.g., transport blanks, transfer blanks, filter blanks, field reagent blanks) may also be analyzed, but are not specifically required by this protocol.

*Equipment rinsate blanks*

The proponent must collect equipment rinsate blanks to verify the adequacy of the decontamination process. This verifies that the equipment is not a source of sample contamination. The proponent should collect equipment rinsate blanks by passing reagent-grade water through clean equipment and collecting samples for chemical analyses. The amount of reagent-grade water used for the sample should represent the volume of stormwater that will be collected during a typical sampling event. These samples should be analyzed as regular samples, with all the appropriate quality control performed.

Equipment rinsate blanks should be collected at the inlet monitoring station where stormwater is expected to contain the highest contaminant concentrations. However, if the inlet station is difficult to access (e.g., confined space entry required), proponents may collect the rinsate blank from the outlet station. At a minimum, proponents must collect three rinsate blanks:

* One rinsate blank after decontaminating the equipment, according to the procedures specified in the QAPP during initial equipment startup
* One rinsate blank after the first or second storm event, following the initial equipment startup (to “contaminate” the equipment)
* One rinsate blank at the end of the monitoring program

**Table 9. Example quality control sample summary for water quality monitoring.**

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Field** | **Laboratory** |
| **Equipment Rinsate Blanks a** | **Field Duplicates b** | **Laboratory Control Samples c** | **Method Blanks c** | **Laboratory Duplicates c** | **MS/MSDs c** |
| TSS | 3 | 10% of samples | 1/batch | 1/batch | 1/batch | NA |
| PSD | NA | 10% of samples | NA | NA | 1/batch | NA |
| pH d | NA | 10% of samples | NA | NA | NA | NA |
| TP | 3 | 10% of samples | 1/batch | 1/batch | 1/batch | 1/batch |
| Total dissolved phosphorus andOrthophosphate | 3 | 10% of samples | 1/batch | 1/batch | 1/batch | 1/batch |

Source: Ecology (2004a)

MS – Matrix Spike

MSD – Matrix Spike Duplicate

NA – not applicable

PSD – particle size distribution

TP – total phosphorus

TSS – total suspended solids

a Required parameters for equipment rinsate blanks depend on the performance goals. For TSS treatment, analyze rinsate blanks for TSS. For phosphorous treatment, analyze rinsate blanks for TSS, TP, total dissolved phosphorus, and orthophosphate.

b Samples are defined as the total number of influent and effluent samples collected (e.g., 5 storm events result in 10 samples). Duplicates must be analyzed for no fewer than 10 percent of samples (e.g., for anywhere between 21 and 30 samples, three duplicates would be required).

c Batches must consist of 20 or fewer samples.

d The field meter used for pH measurements should be calibrated before and after each use.

Proponents should consider collecting more frequent rinsate blank samples following an event with unusually high contaminant concentrations.

The QAPP must describe the location and number of rinsate blanks that will be collected, sample collection and processing procedures, and sample documentation (e.g., length of time that sampler was in place before collecting the blank, and volume of stormwater that passed through the sampler before cleaning the equipment).

If any parameters are detected at levels greater than the reporting limit in the equipment rinsate blank, the field sampling crew should be notified so that the source of contamination can be identified and corrective actions taken prior to the next sampling event. The proponent should describe potential corrective actions in the QAPP (e.g., modifying decontamination procedures, replacing suction tubing, altering the reporting limit for samples already collected).

If the concentration in the associated flow-proportional samples is less than ten times the value in the equipment rinsate blank, the results for the collected samples may be unacceptably affected by contamination and should be qualified as appropriate. If contamination is detected, and the laboratory method blank results rule out the laboratory as a source of contamination, then equipment rinsate blanks must be collected at a rate of 100 percent of samples until the source of contamination is eliminated. Other types of field blanks that may help to locate the source of contamination include transport blanks, transfer blanks, and equipment rinsate blanks that isolate portions of the monitoring equipment (e.g., sample tubing, pump tubing). If the source of contamination cannot be located or eliminated, the proponent must inform the MPCA and discuss options for continuing monitoring at the site.

*Field Duplicate Samples*

A field duplicate is a second independent sample collected at the same time and location as the original sample. Field duplicates are primarily used to assess the variation attributable to sample collection procedure and sample matrix effects. The QAPP must describe the technique that will be used to collect duplicate samples and specify the collection frequency. At a minimum, the proponent must collect field duplicates for 10 percent of the samples collected (i.e., 10 percent of the influent and effluent samples from all monitoring sites combined).

## Equipment maintenance and calibration

Equipment must be installed and maintained in accordance with the manufacturer’s recommendations, and the QAPP must indicate any deviations from these recommendations. An equipment maintenance schedule must be provided in this section of the QAPP that includes the field equipment calibration schedule and procedures for rain gauges, flow monitoring equipment, automated samplers, and pH field meters (see example in Table 10). It is recommended that the proponent use AC power whenever possible to avoid issues associated with power failure of battery-powered systems.

## Laboratory quality control

In the laboratory QC section of the QAPP, the proponent must describe the laboratory’s data quality assurance summary package requirements (i.e., case narrative, performance evaluations [PE], certified reference materials [CRM], laboratory control samples, method blanks, MS/MSDs, laboratory duplicates, surrogates, and reference samples). Laboratory control samples, method blanks, laboratory duplicates, and MS/MSDs must be analyzed with each batch. For metals, at least two separate pairs of MS/MSDs per year should be performed on samples specifically from this project.

The QAPP must include a table listing all QC samples being performed (see example in Table 10). Quality control results may indicate problems with the data, thus corrective actions

(i.e., re-calibrations, re-analyses of samples, need to re-sample, need for additional samples, or qualifying results) should be included in the QAPP.

**Table 10. Example equipment maintenance and calibration schedule.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Equipment** | **Item** | **Procedure** | **Minimum Frequency** |
| Rain gauge | Funnel and screen | Check for debris | Monthly |
| Level check | Verify level with bubble indicator | Monthly |
| Calibration | Calibrate in accordance with manufacturer’s instructions | At installation and once annually |
| Flow monitoring | Desiccant | Check color – when pink, exchange for new desiccant | Every visit |
| Vent tubing | Check for obstructions | Every visit |
| Calibration | Calibrate in accordance with manufacturer’s instructions | At installation and monthly |
| Automated sampler | Pump tubing | Check integrity | Every visit |
| Sample tubing and intake | Check integrity; verify no obstructions at intake | Every visit |
| Humidity indicator | Check surface indicator | Every visit |
| pH field meter | Calibration | Calibrate in accordance with manufacturer’s instructions | Before and after each use |

# Data management procedures

The QAPP must include requirements for the data package from the laboratory or laboratories selected for the project (i.e., detailed case narrative that discusses problems with the analyses, corrective actions if applicable, deviations from analytical methods, QC results, and a complete definitions list for each qualifier used). The QAPP must specify field/laboratory electronic data transfer protocols, state the percent of data that will undergo QC review, and describe corrective procedures. Corrections to data entries should include initials of the person making the correction and the date corrected. The QAPP must also indicate where and how the data will be stored.

# Data verification and validation

The QAPP must describe the process that will be used to verify and validate the hydrologic and water quality data. The proponent should review all data to ensure they are consistent, correct and complete, and that all required quality control information has been provided. Specific quality control elements for the data must also be examined to determine if the MQOs for the project have been met.

## Data quality assessment

This section of the QAPP must describe the data quality assessment procedures that will be used to establish the usability of the data. If the MQOs have been met, then data quality should be usable for meeting project objectives. If the MQOs have not been met for data (i.e., the data have been qualified), the proponent will need to determine if they are still usable. The data quality assessment procedures must include an assessment of whether the requirements for representativeness, completeness, and comparability have been met (see *Quality Objectives* section).

This section of the QAPP must also include the following information related to the analysis of the data:

* Summary of the methods that will be used to analyze and present the data
* Description of any statistical calculations and graphical representations that will be used
* Description of how the data will be presented (e.g., tables or charts) to illustrate trends, relationships, and anomalies, and how data below the lower reporting limit or detection limit will be handled.
* Description of how monitoring site and data will be evaluated to determine if the sampling design has been adequate

Washington State’s TAPE program requires submittal of a Technical Evaluation Report (TER). The MPCA does not require a TER but instead requires an addendum report, described in Appendix B, summarizing any modifications to the TAPE TER for the device and a summary of additional analysis and analysis reports. Guidelines and format requirements (e.g. concentration units, times, etc.) specified in Washington State’s “Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies” (August 2011 revision or Publication no. 02-10-03/Publication no. 11-10-061) must be used in the addendum report. This addendum report can be prepared by the vendor/manufacturer, an independent professional third party that developed the QAPP and conducted the monitoring program for the vendor/manufacturer, or another independent professional third party. If the vendor/manufacturer prepares the addendum report, a separate third-party review memorandum is required (described at the end of this document).

Proponents may request that certain records or other information be considered confidential. Such requests will be considered by the MPCA. In order for such records or information to be considered confidential, the proponent must certify that the records or information is unique to the design and construction of the technology, or release to the public or to a competitor would adversely affect the competitive position of the proponent. The proponent must request that such records or information be made available only for the confidential use of MPCA. All monitoring data including, but not limited to, laboratory results and field measurements, QA/QC data, data qualifiers, and monitoring site information cannot be considered confidential.

To make a request for confidentiality, the proponent must clearly mark only those pages that contain confidential material with the word “confidential” and submit these pages as a separate file from the addendum report to MPCA. Placeholder pages must be placed in the addendum report that state “confidential material has been provided as a separate document to the MPCA.” The proponent must also provide a letter of explanation as to why these pages are confidential. MPCA will review the request and send notice to the proponent either granting or denying the confidentiality. Proponents may request return of material if MPCA denies the request for confidentiality.

## Third-party review

For all submittals that contain field monitoring data that was collected by a vendor or manufacturer of a stormwater treatment technology, an independent professional third party must prepare a third-party review memorandum that contains the following elements:

* A signature page verifying that the opinions contained in the review memorandum are that of an independent third-party reviewer and no conflict of interest is present.
* A data validation review verifying that the site setup was performed according to the QAPP, and that monitoring was conducted in accordance with this protocol and the QAPP.
* A data summary that includes a review of monitoring data and ISRs from all sampled storm events, a test results summary, conclusions, and a comparison with the vendor or manufacturer’s performance claims.
* For TP, a recommendation of the appropriate Tier level designation for the treatment system.
* Additional testing recommendations, if needed.

If the field monitoring was conducted by an independent professional third party, and the addendum was also prepared by the same or a different independent professional third party, then a third- party review memorandum is not required.

# References

APHA, AWWA, and WEF. 2005. Standard Methods for the Examination of Water and Wastewater, 21th Edition. American Public Health Association, American Water Works Association, and Water Environment Federation, Washington, D.C.

APWA. 1999. Protocol for the Acceptance of Unapproved Stormwater Treatment Technologies for Use in the Puget Sound Watershed. Prepared by the APWA Task Committee for American Public Works Association, Washington Chapter, Stormwater Managers Committee, Washington.

ASTM. 2002. Standard test methods for determining sediment concentration in water samples. Method D 3977. American Society for Testing and Materials, Philadelphia, Pennsylvania.

Ecology. 1997. Analytical Methods for Petroleum Hydrocarbons. No. ECY 97-602. Washington State Department of Ecology, Toxics Cleanup Program and Environmental Laboratory, Olympia, Washington.

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

Ecology, 2004b. Stormwater Management Manual for Eastern Washington. No. 04-10-076. Washington State Department of Ecology, Olympia, Washington. September 2004.

Ecology. 2005. Stormwater Management Manual for Western Washington. No. 05-10-029 through 05-10-033. Washington State Department of Ecology, Olympia, Washington. February 2005.

Ecology. 2007. Western Washington Phase I Municipal Stormwater Permit. Washington State Department of Ecology Water Quality Program. Issued January 17, 2007, modified June 17, 2009.

Ecology. 2008. Guidance for Evaluating Emerging Stormwater Treatment Technologies- Technology Assessment Protocol—Ecology (TAPE)—Modification: Evaluating Stormwater Treatment Technologies with Long Detention Times. DRAFT Washington State Department of Ecology, Olympia, Washington. March 27, 2008.

Ecology. 2009a. Standard Operating Procedure for Automatic Sampling for Stormwater Monitoring, Version 1.0. No. ECY 002. Washington State Department of Ecology, Olympia, Washington. September 16, 2009.

Ecology. 2009b. Standard Operating Procedure for Collecting Grab Samples from Stormwater Discharges, Version 1.0. No. ECY 001. Washington State Department of Ecology, Olympia, Washington. September 16, 2009.

Ecology. 2011a. Emerging Stormwater Treatment Technologies Application for Certification. No. ECY 070-391. Washington State Department of Ecology, Olympia, Washington.

Ecology. 2011b. Technology Assessment Protocol – Ecology (TAPE) Process Overview. No. 11-10-010. Washington State Department of Ecology, Olympia, Washington.

Efron, B. and R.J. Tibshirani. 1993. An introduction to the bootstrap: Monographs on statistics and applied probability. Chapman & Hall, New York.

Helsel, D.R. and R.M. Hirsch. 2002 . Statistical Methods in Water Resources. Elsevier Publications, Amsterdam.

Porter, P.S., S.T. Rao, J.Y Ku, R.L. Poirot, and M. Dakins. 1997. Small sample properties of nonparametric bootstrap t confidence intervals. *Journal of the Air and Waste Management Association* 47:1197-1203.

U.S. EPA, November 1997. Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls, EPA 841-B-96-004. U. S. Environmental Protection Agency, Nonpoint Source Control Branch, Washington, D.C.

U.S. EPA. 1995. EPA Clean Water Act Section 403 Report to Congress, NPDES Permitting Program, EPA 842-R-94-001. U.S. Environmental Protection Agency, Washington, D.C.

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

Washington Stormwater Center and Herrera. 2011. Defining enhanced treatment for the Technology Assessment Protocol – Ecology (TAPE). Prepared by the Washington Stormwater Center, Tacoma, Washington and Herrera Environmental Consultants, Inc., Seattle, Washington. April 25, 2011.

Wentworth, C.K. 1922. A scale of grade and class terms for sediments. *Journal of Geology*

30:377-392.

# Glossary

**Accreditation –** A certification process for laboratories, designed to evaluate and document a lab’s ability to perform analytical methods and produce acceptable data.

**Accuracy** – the degree to which a measured value agrees with the true value of the measured property. The terms precision and bias are often used to convey the information associated with this term.

**Absorption –** The penetration of a substance into or through another, such as the dissolving of a soluble gas in a liquid.

**Adsorption** – The adhesion of a substance to the surface of a solid or liquid; often used to extract pollutants by causing them to be attached to such adsorbents as activated carbon or silica gel. Heavy metals such as zinc and lead often adsorb onto sediment particles.

**Analyte** – An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined.

**Anion exchange** – The chemical process where negative ions of one chemical are preferentially replaced by negative ions of another chemical.

**Automated sampler** – A portable unit that can be programmed to collect discrete sequential samples, time-composite samples, or flow-composite samples.

**Backwater –** Water upstream from an obstruction which is deeper than it would normally be without the obstruction.

**Basic treatment** – Treatment of stormwater with the goal of removing at least 80 percent of the solids present in the runoff. Receiving waters and areas subject to this treatment requirement are specified in the SWMMWW and SWMMEW. Additional treatment to remove metals, oil or phosphorus may be required at some sites or for some receiving water bodies.

**Best management practice (BMP) –** The schedules of activities, prohibitions of practices, maintenance procedures, and structural and/or managerial practices, that when used singly or in combination, prevent or reduce the release of pollutants and other adverse impacts to waters of Washington State.

**Bias** – The difference between the population mean and the true value. Bias usually describes a systematic difference reproducible over time, and is characteristic of both the measurement system, and the analyte(s) being measured.

**Blank** – A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process.

**Bypass –** A design feature that allows flow rates or flow volumes higher than the design hydraulic loading rate to be routed past the stormwater treatment technology without receiving treatment.

**Calibration** – The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured.

**Cation exchange –** A process where positively charged ions of one chemical are preferentially replaced by positive ions of another chemical.

**Comparability –** The degree to which different methods, datasets and/or decisions agree or can be represented as similar.

**Completeness –** The amount of valid data obtained from a data collection project compared to the planned amount. Completeness is usually expressed as a percentage.

**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.

**Confined space entry** – 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.

**Control chart** – A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system.

**Control limits** – Statistical warning and action limits calculated based on control charts. Warning limits are generally set at ± 2 standard deviations from the mean, action limits at

± 3 standard deviations from the mean.

**Dataset –** A grouping of samples, usually organized by date, time, and/or analyte.

**Data validation** – An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the analytical quality of a specific dataset. It involves a detailed examination of the data package using professional judgment to determine whether the MQOs for precision, bias, and sensitivity have been met.

**Data verification** – Examination of the data for errors or omissions and of the quality control results for compliance with acceptance criteria.

**Design storm –** A prescribed hyetograph and total precipitation amount (for a specific duration recurrence frequency) used to estimate runoff for a hypothetical storm of interest or concern for the purposes of analyzing existing drainage, designing new drainage facilities or assessing other impacts of a proposed project on the flow of surface water. (A hyetograph is a graph of percentages of total precipitation for a series of time steps representing the total time during which the precipitation occurs.)

**Detention –** The release of stormwater runoff from the site at a slower rate than it is collected by the stormwater facility system, the difference being held in temporary storage.

**Detention time –** The theoretical time required to displace the contents of a stormwater treatment facility at a given rate of discharge (volume divided by rate of discharge).

**Dissolved metals treatment** –Treatment of stormwater with the goal of removing dissolved metals (i.e., copper and zinc) present in the runoff. Receiving waters and areas subject to this treatment requirement are specified in the SWMMWW and SWMMEW. Additional treatment to remove oil or phosphorus may be required at some sites or for some receiving water bodies.

**Drainage area** – The area contributing runoff to a single point measured in a horizontal plane, which is enclosed by a ridge line.

**Drainage** – Refers to the collection, conveyance, containment, and/or discharge of surface and stormwater runoff.

**Effluent** – Discharge from the outlet that is not comingled with stormwater bypassing the stormwater treatment technology.

**Emerging technology –** Treatment technologies that have not been evaluated with approved protocols, but for which preliminary data indicate that they may provide a necessary function(s) in a stormwater treatment system. Emerging technologies need additional evaluation to define design criteria to achieve, or to contribute to achieving, state performance goals, and to define the limits of their use.

**Erosion –** The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. This term also includes detachment and movement of soil or rock fragments by water, wind, ice, or gravity.

**Equipment rinsate blank –** A quality control sample collected by passing reagent-grade water through clean equipment and collecting samples for chemical analyses. The amount of reagent- grade water used for the sample should represent the volume of stormwater that will be collected during a typical sampling event. The equipment rinsate blank may also detect contamination from the surroundings, contamination from the containers, or from cross-contamination during transportation and storage of the samples and is therefore the most comprehensive type of field blank.

**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.

**Field blank** – A blank used to obtain information on contamination introduced during sample collection, storage, and transport. Includes transport blanks, transfer blanks, equipment rinsate blanks, and filter blanks.

**Field duplicates –** Separate samples collected simultaneously at the identical source location and analyzed separately. Field duplicates are used to assess total sample variability (i.e., field plus analytical variability).

**Filter blank –** A special case of a rinsate blank prepared by filtering pure water through the filtration apparatus after routine cleaning that may detect contamination from the filter or other part of the filtration apparatus.

**Filtration –** Use of various media such as sand, perlite, zeolite, and carbon, to remove low levels of total suspended solids (TSS). Specific media such as activated carbon or zeolite can remove hydrocarbons and soluble metals. Filter systems can be configured as basins, trenches, or cartridges.

**Frequency of storm (design storm frequency)** – The anticipated period in years that will elapse, based on average probability of storms in the design region, before a storm of a given intensity and/or total volume will recur; thus a 10-year storm can be expected to occur on the average once every 10 years.

**Gauge –** Device for registering precipitation, water level, discharge, velocity, pressure, temperature, etc.

**General use level designation (GULD)** – A use level designation assigned by Ecology for emerging technologies that have achieved the monitoring and reporting requirements specified in the TAPE protocol. This use level designation confers a general acceptance for the treatment technology. Technologies with this use level designation may be installed anywhere in Washington, subject to Ecology’s conditions.

**Grab sample –** A sample collected during a very short time period at a single location.

**Groundwater –** Water in a saturated zone or stratum beneath the land surface or a surface waterbody.

**Head (hydraulics) –** The height of water above any plane of reference. The energy, either kinetic or potential, possessed by each unit weight of a liquid, expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. Used in various compound terms such as pressure head, velocity head, and head loss.

**Head loss –** Energy loss due to friction, eddies, changes in velocity, or direction of flow.

**Hydraulic gradient –** Slope of the potential head relative to a fixed datum.

**Hydrograph** – A graph of runoff rate, inflow rate or discharge rate past a specific point as a function of time.

**Illicit connection –** Any man-made conveyance that is connected to a municipal separate storm sewer without a permit, excluding roof drains and other similar type connections. Examples include sanitary sewer connections, floor drains, channels, pipelines, conduits, inlets, or outlets that are connected directly to the municipal separate storm sewer system.

**Impervious surface –** A hard surface area which either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development. A hard surface area which causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under natural conditions prior to development. Common impervious surfaces include, but are not limited to, roof tops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled, macadam or other surfaces which similarly impede the natural infiltration of stormwater. Open, uncovered retention/detention facilities shall be considered impervious surfaces for purposes of runoff modeling.

**Infiltration** – The downward movement of water from the surface to the subsoil.

**Influent** – Stormwater runoff entering the inlet of the stormwater treatment technology.

**Inlet –** A form of connection between surface of the ground and the stormwater treatment technology for the admission of surface and stormwater runoff.

**Laboratory control sample (LCS)** – A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples.

**Laboratory replicates –** Repeated analyses of a variable performed on the contents of a single sample bottle. Laboratory replicates are used to assess analytical precision. Duplicate analyses are sufficient for procedures that are well proven in the laboratory.

**Lag time –** The detention time for a stormwater treatment technology that occurs between the inlet and outlet.

**Maintenance –** Repair and maintenance includes activities conducted on currently serviceable structures, facilities, and equipment that involves no expansion or use beyond that previously existing and resulting in no significant adverse hydrologic impact. It includes those usual activities taken to prevent a decline, lapse, or cessation in the use of structures and systems and includes replacement of disfunctioning facilities, including cases where environmental permits require replacing an existing structure with a different type structure, as long as the functioning characteristics of the original structure are not changed.

**Matrix spike (MS) and matrix spike duplicate (MSD)** – A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects.

**Measurement quality objectives (MQOs)** – Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness.

**Method** – A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed.

**Method blank** – A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples.

**Monitoring –** The collection of data by various methods for the purposes of understanding natural systems and features, evaluating the impacts of development proposals on such systems, and assessing the performance of mitigation measures imposed as conditions of development.

**National Pollutant Discharge Elimination System (NPDES) –** The part of the federal Clean Water Act, which requires point source dischargers to obtain permits. These permits are referred to as NPDES permits and, in Washington State, are administered by the Washington State Department of Ecology.

**New development –** Land disturbing activities, including Class IV-general forest practices that are conversions from timber land to other uses; structural development, including construction or installation of a building or other structure; creation of impervious surfaces; and subdivision, short subdivision and binding site plans, as defined and applied in Chapter 58.17 RCW. Projects meeting the definition of redevelopment shall not be considered new development.

**Nutrients –** Essential chemicals needed by plants or animals for growth. Excessive amounts of nutrients can lead to degradation of water quality and algal blooms. Some nutrients can be toxic at high concentrations.

**Off-line facilities –** Water quality treatment facilities to which stormwater runoff is restricted to some maximum flow rate or volume by a flow-splitter.

**On-line facilities –** Water quality treatment facilities which receive all of the stormwater runoff from a drainage area. Flows above the water quality design hydraulic loading rate or volume are passed through at a lower percent removal efficiency.

**Outlet –** Point of water disposal from a stormwater treatment technology.

**Parameter** – A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Total suspended solids, total phosphorus, and total petroleum hydrocarbons are all “parameters”.

**Particle size –** The effective diameter of a particle as measured by sedimentation, sieving, or micrometric methods.

**Percent relative standard deviation (%RSD)** – A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

%RSD = (100 \* s)/x where s = sample standard deviation, and x = sample mean

**Pervious surface –** A surface that allows infiltration of stormwater into the underlying soil. Common pervious surfaces include, but are not limited to, lawns, pastures, and forests.

**pH –** A measure of the alkalinity or acidity of a substance which is conducted by measuring the concentration of hydrogen ions in the substance.

**Phosphorus treatment** –Treatment of stormwater with the goal of removing 50 percent of the total phosphorus present in the runoff. Receiving waters and areas subject to this treatment requirement are specified in the SWMMWW and SWMMEW. This type of treatment is required only where federal, state, or local government has determined that a water body is sensitive to phosphorus and that a reduction in phosphorus from new development and redevelopment is necessary to achieve water quality standards. Additional treatment to remove metals or oil may be required at some sites or for some receiving water bodies.

**Pollutant –** A contaminant in a concentration or amount that adversely alters the physical, chemical, or biological properties of the natural environment. Dredged soil, solid waste, incinerator residue, filter backwash, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials (except those regulated under the Atomic Energy Act of 1954, as amended), heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water.

**Pollutant load** – A mass concentration multiplied by the total volume of water passing by a certain point in time.

**Precision** – The extent of random variability among replicate measurements of the same property.

**Pretreatment –** The removal of material such as solids, grit, grease, and scum from flows prior to physical, biological, or physical treatment processes to improve treatability. Pretreatment may include screening, grit removal, settling, oil/water separation, or application of a Basic Treatment BMP prior to infiltration.

**Proponent –** The person(s) who would like to certify their stormwater treatment technology through the TAPE process. This can include the designer, manufacturer, vendor, and their consultant(s).

**Quality assurance (QA)** – A set of activities designed to establish and document the reliability and usability of measurement data.

**Quality Assurance Project Plan (QAPP)** – A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives.

**Quality control (QC)** – The routine application of measurement and statistical procedures to assess the accuracy of measurement data.

**Redevelopment –** On a site that is already substantially developed (i.e., has 35 percent or more of existing impervious surface coverage), the creation or addition of impervious surfaces; the expansion of a building footprint or addition or replacement of a structure; structural development including construction, installation or expansion of a building or other structure; replacement of impervious surface that is not part of a routine maintenance activity; and land disturbing activities.

**Retrofitting –** The renovation of an existing structure or facility to meet changed conditions and/or to improve performance.

**Relative percent difference (RPD)** – The difference between two values divided by their mean and multiplied by 100.

**Reporting limit –** The lowest amount of an analyte in a sample that can be quantitatively determined with stated, acceptable precision and accuracy under stated analytical conditions (i.e., the lower limit of quantitation).

**Representativeness –** The degree to which a sample reflects the population from which it is taken.

**Return frequency –** A statistical term for the average time of expected interval that an event of some kind will equal or exceed given conditions (e.g., a stormwater flow that occurs every

2 years).

**Runoff –** Water originating from rainfall and other precipitation that is found in drainage facilities, rivers, streams, springs, seeps, ponds, lakes and wetlands as well as shallow ground water. It also means the portion of rainfall or other precipitation that becomes surface flow and interflow.

**Sensitivity** – In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit.

**Settleable solids –** Those suspended solids in stormwater that separate by settling when the stormwater is held in a quiescent condition for a specified time.

**Settling** – The process by which particulates settle to the bottom of a liquid and form a sediment.

**Slope –** Degree of deviation of a surface from the horizontal; measured as a numerical ratio, percent, or in degrees. Expressed as a ratio, the first number is the horizontal distance (run) and the second is the vertical distance (rise), as 2:1.

**Soil Conservation Service** (**SCS) Method –** A single-event hydrologic analysis technique for estimating runoff based on the Curve Number method. The Curve Numbers are published by NRCS *in Urban Hydrology for Small Watersheds, 55 TR, June 1976*.

**Standard operating procedure (SOP)** – A document which describes in detail a reproducible and repeatable organized activity.

**Steep slope –** Slopes of 40 percent gradient or steeper within a vertical elevation change of at least ten feet. A slope is delineated by establishing its toe and top, and is measured by averaging the inclination over at least ten feet of vertical relief.

**Stormwater –** That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, pipes and other features of a stormwater drainage system into a defined surface waterbody, or a constructed infiltration facility.

**Stormwater facility –** A constructed component of a stormwater drainage system, designed or constructed to perform a particular function, or multiple functions. Stormwater facilities include, but are not limited to, pipes, swales, ditches, culverts, street gutters, detention ponds, retention ponds, constructed wetlands, infiltration devices, catch basins, oil/water separators, and biofiltration swales.

**Surrogate** – For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples.

They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis.

**Total suspended solids (TSS) –** That portion of the solids (organic or inorganic particles including sand, mud, and clay particles and associated pollutants) carried by stormwater that can be captured on a standard glass filter.

**Transfer blank –** A sample container of pure water, which is prepared at the laboratory and carried unopened to the field and back with the other sample containers to check for possible contamination in the containers or for cross-contamination during transportation and storage of the samples.

**Transport blank –** A sample container of pure water which is filled during routine sample collection to check for possible contamination from the surroundings, contamination from the containers, or from cross-contamination during transportation and storage of the samples.

**Treatment BMP –** A BMP that is intended to remove pollutants from stormwater. A few examples of treatment BMPs are wet ponds, oil/water separators, biofiltration swales, and constructed wetlands.

**Treatment train –** A combination of two or more treatment facilities connected in series.

**Vortexing separation** – Physical stormwater treatment technology that employs the use of cylindrical chambers to induce rotational forces that separate settleable solids and associated pollutants.

**Water quality –** A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

**Water quality design storm –** The 24-hour rainfall amount with a 6-month return frequency. Commonly referred to as the 6-month, 24-`hour storm.

# Appendix A: Summary of modifications to TAPE protocol

Because this document was adopted from Washington State’s guidance for QAPP submittals, some modifications were required for applicability in Minnesota. Those modifications are shown in yellow text in this document and are summarized below.

* **NOTE: The proponent may submit the QAPP from the TAPE study with a QAPP addendum. Appendix B describes the necessary components of a QAPP addendum.**
* Washington State’s TAPE program requires submittal of a Technical Evaluation Report (TER). The MPCA does not require a TER but instead requires an addendum report, described in Appendix B, summarizing any modifications to the TAPE TER for the device and a summary of additional analysis and analysis reports. Guidelines and format requirements (e.g. concentration units, times, etc.) specified in Washington State’s “Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies” (August 2011 revision or Publication no. 02-10-03/Publication no. 11-10-061) must be used in the addendum report. This addendum report can be prepared by the vendor/manufacturer, an independent professional third party that developed the QAPP and conducted the monitoring program for the vendor/manufacturer, or another independent professional third party. If the vendor/manufacturer prepares the addendum report, a separate third-party review memorandum is required (described at the end of this document).
* A minimum of 15 samples must be collected over a minimum of one full calendar year.

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Definition** | **Guideline a** |
| Minimum storm depth | Total rainfall amount during the storm event | 10th percentile one-year storm event |
| Storm start (antecedent dry-period) | Defines the storm event’s beginning as designated by minimum time interval without significant rainfall | 12 hours minimum with less than 0.04 inches of rain |
| Storm end (post storm dry period) | Defines the storm event’s end as designated by minimum time interval without significant rainfall | 12 hours minimum with less than 0.04 inches of rain |

* Maximum sampling duration is 24 hours
* Flow must be logged at a 5-minute or shorter interval, depending on site conditions
* Minnesota does not require an mtd to meet a specific performance goal. Sizing of an mtd for the designed hydraulic loading rate must be reported in the QAPP or QAPP Addendum (see Appendix B). Acceptable methods for sizing a device are [discussed in the Minnesota Stormwater Manual.](https://stormwater.pca.state.mn.us/index.php?title=TP_and_TSS_credits_and_guidance_for_manufactured_treatment_devices_(mtds)#Calculating_annual_volume_treated)
* Influent concentration ranges are specified below
	+ TSS: 20-200 mg/L
	+ TP: 0.10-0.80 mg/L
	+ TDP: 0.05-0.50 mg/L
* Required sampling parameters
	+ TSS
	+ TP
		- TSS
		- TDP
		- OP
	+ pH
	+ Particle size distribution
* Samples of dissolved phosphorus and orthophosphate (PO4) shall be filtered with a disposable 0.45 μm glass fiber filter at the laboratory prior to analysis. If laboratory analyses cannot be accomplished within the applicable hold time, the respective samples shall be preserved through freezing of the sample at the laboratory. If preservation through freezing cannot be accomplished, the sample will be discarded.
* The proponent may collect and submit for analysis samples filtered in the field **in addition to** samples filtered in the laboratory. Field-filtered samples of dissolved phosphorus and orthophosphate (PO4) shall be filtered with a disposable 0.45 μm glass fiber filter. In-line filtration is preferred, but hand-pumped filtration (e.g. for composite samples) is acceptable. The MPCA will evaluate both laboratory- and field-filtered samples in its analysis.
* **Required particle size distribution size categories for the modified suspended sediment concentration method.**

|  |  |  |
| --- | --- | --- |
| **Size Category (µm) a,b** | **Particle Description** | **Analysis Method c** |
| > 500 | Greater than medium sand | Retained on No. 35 sieve |
| 250 - 500 | Medium sand | Passing No. 35 sieve and retained on No. 60 sieve |
| 125-250 | Fine sand | Passing No. 60 sieve and retained on No. 125 sieve |
| 62.5 - 125 | Very fine sand | Passing No. 125 sieve and retained on No. 230 sieve |
| 4 – 62.5 | Silt | Passing No. 230 sieve and retained on No. 325 sieve |
| < 4 | Clay and colloidal | Passing No. 325 sieve |

# Appendix B: Preparing an addendum report

Proponents may, and are encouraged, to submit the QAPP from the Washington State TAPE monitoring study for the proposed device. If the proponent prepares a new QAPP for submission to the MPCA, the QAPP must include the information described in this document. If a proponent submits the QAPP from the TAPE study, the proponent must submit an addendum which contains the following information, if applicable.

## General

* Project objectives (i.e., characterizing pollutant removal effectiveness and effluent quality at the design hydraulic loading rate)
* Information (i.e., data) that will be required to meet the project objectives
* Number of test locations and approximate duration of monitoring
* Tasks that will be required to collect the data
* Potential constraints (i.e., seasonal or meteorological conditions, limited access, safety, or availability of personnel or equipment)

## Organization and schedule

* Name, organization, and phone numbers of key members of the project team (i.e., project manager, test site owner/manager, field personnel, consultant oversight participants, and analytical laboratory contacts)
* Identification of who will perform the third-party evaluation
* Roles and responsibilities of the key members of the project team
* Project schedule documenting when the treatment system and associated monitoring equipment will be installed, the expected field monitoring start date, projected field sampling completion, and addendum report submittal

## Monitoring and site information

* Drainage area contributing to the treatment system, land use (e.g., roadway, commercial, high-use site, residential, industrial), percentage of drainage area that is impervious, and percentage of drainage area that is pervious. A description of the types of vegetation present in the drainage area should also be included.
* Description of potential pollutant sources in the drainage area (e.g., parking lots, roofs, landscaped areas, sediment sources, exterior storage, or process areas).
* Baseline stormwater quality information to characterize conditions at the site. For sites that have already been developed, it is recommended that the proponent collect baseline data to determine whether site conditions and runoff quality are conducive to performance monitoring.
* Vicinity map showing site location, drainage area, impervious area, slopes, existing drainage system, and other important hydrologic information.
* Site schematic in plan and profile showing treatment system and monitoring equipment locations.
* Latitude and longitude of the treatment system.
* Drainage area flow rates (i.e., water quality design flow, 2-year, 10-year, and 100-year recurrence interval peak flow rates) at 15-minute and 1-hour time steps as provided by an approved continuous runoff model.
* Make, model, and hydraulic capacity of the treatment system.
* Location and description of the closest receiving water body.
* Description of bypass flow rates or flow splitter designs necessary to accommodate the treatment facility.
* Description of pretreatment system, if required by site conditions or treatment system operation.
* Description of any known adverse site conditions such as climate, high groundwater, rainfall pattern, steep slopes, erosion, high spill potential, illicit connections to stormwater drainage system, or industrial runoff.
* Photo documentation of site conditions.
* Any modifications to the QAPP submitted and approved for the TAPE study
* The type of rain gauge used (e.g., an automatic recording electronic rain gauge, such as a tipping bucket connected to a data logger, that records rainfall in 0.01-inch increments) and make and model number of the selected rain gauge. The rain gauge location must be shown on the site schematic if it is located at the monitoring site or on the vicinity map if it is in another portion of the drainage basin.
* Location of third-party rain gauges in the event the primary rain gauge fails
* Identify the make and model number of the selected flow monitoring equipment. Additionally, the flow monitoring equipment locations must be identified in the QAPP on the site schematic in plan and profile.
* Identify site conditions (e.g., high groundwater levels) that could affect flow measurement accuracy.
* Identify the make and model number of the selected flow monitoring equipment. Additionally, the flow monitoring equipment locations must be identified in the QAPP on the site schematic in plan and profile.
* Identify the make and model number of the selected automated sampling equipment and the pH field meter. Additionally, the automated sampler locations must be identified in the QAPP on the site schematic.

# Appendix C: Determining credits for manufactured treatment devices (mtds)

Credit, as applied here, means the difference in amount of pollutant leaving an mtd (i.e. after treatment) and the amount entering an mtd (i.e. prior to treatment), expressed as a percent. For example, if the concentration of a pollutant entering an mtd is 100 mg/L, and the concentration leaving the mtd is 50 mg/L, the credit or pollutant removal is 50 percent. Credit does not represent annual pollutant reduction, which is total amount or mass of pollutant removed by an mtd annually. Annual pollutant removal is the product of the credit times the percent of annual runoff treated by the mtd. Methods for calculating annual removal are [described in the Minnesota Stormwater Manual](https://stormwater.pca.state.mn.us/index.php?title=TP_and_TSS_credits_and_guidance_for_manufactured_treatment_devices_(mtds)#Calculating_annual_volume_treated).

Methods for determining credits are described below.

* TSS credit is determined as follows:
	+ The lower 95% confidence limit (LCL) for all samples from TAPE monitoring, calculated using Washington TAPE’s Bootstrap Calculator or
	+ the LCL for all samples from other monitoring that follows [monitoring protocol described here](https://stormwater.pca.state.mn.us/index.php?title=TP_and_TSS_credits_and_guidance_for_manufactured_treatment_devices_(mtds)#Protocol_for_monitoring), calculated using Washington TAPE’s Bootstrap Calculator.
	+ If the LCL is less than 80%, MPCA staff may assign a value of 80% if additional analysis and review indicates the device is likely to achieve 80% TSS removal under most storm runoff conditions. Factors considered in this determination include but are not limited to low influent TSS concentrations during monitoring, exceptionally small particle size in monitoring runoff, or laboratory analysis under conditions considered more representative of runoff than conditions that existed during field monitoring.
* Tier 1 - TP
	+ Credit: 50 percent reduction
	+ Conditions for receiving credit
		- Inspect manufactured treatment device a minimum of twice during year 1. Conduct inspections following manufacturer’s instructions/recommendations. Use maintenance indicators provided by manufacturers to determine if maintenance is needed. Maintenance procedures should follow manufacturer’s guidelines. After year 1, follow manufacturers inspection, operation, and maintenance schedule and procedures unless otherwise required or unless year 1 inspections indicate a need for increased inspection and/or operation and maintenance. Determine future inspection and maintenance schedules from findings during the first year of operation.
		- Comply with appropriate configurations and Use conditions from TAPE. These can be found on the individual device pages (see links below).
* Tier 2 - TP
	+ Credit: based on the lower of three values, calculated as follows.
		- The LCL for samples with influent concentrations between 0.1 and 0.5 mg/L, calculated using Washington TAPE’s Bootstrap Calculator, or
		- the LCL for samples with influent concentrations between the 5th percentile TP concentration, as defined below, and 0.5 mg/L, calculated using Washington TAPE’s Bootstrap Calculator, or
		- TP removal calculated using the equation TPR=(PPF∗TSSR) = (0.75∗TSSR) where PPF is the fraction of TP in particulate form, assumed to be 0.75 (75 percent) and TSSR is the LCL for TSS defined in item 3 above.
	+ The Tier 2 TP credit cannot exceed 60%. If values calculated using the above methods is less than 50%, no Tier 2 credit is given.
	+ Conditions for receiving credit:
		- Must meet Tier 1 conditions.
		- DP should be 25 percent or less of TP. Since monitoring will not likely be implemented for these devices, [we provide guidance below](https://stormwater.pca.state.mn.us/index.php?title=TP_and_TSS_credits_and_guidance_for_manufactured_treatment_devices_(mtds)#Applicability_of_Tier_2_TP_credits) for determining if site conditions may affect the credit.
		- Inspect manufactured treatment device monthly during the frost free season for the first year of operation after construction. Conduct inspections following manufacturer’s instructions/recommendations. Use maintenance indicators provided by manufacturers to determine if maintenance is needed. Maintenance procedures should follow manufacturer’s guidelines.

The 5th percentile TP concentration represents a concentration which is exceeded in 95% of samples. This value is subject to change based on the best available data. Changes in the 5th percentile TP concentration will affect the Tier 2 TP credit. As of January, 2022, the [National Stormwater Quality Database](https://bmpdatabase.org/national-stormwater-quality-database), EPA Rainfall Region 1, is used to estimate the 5th percentile TP concentration. This value is 0.05 mg-TP/L (n=598). Note: [a study being conducted by University of Minnesota researchers](https://www.wrc.umn.edu/leveraging-minnesotas-stormwater-resources) will likely provide a more reliable dataset for Minnesota runoff and would therefore replace the NSQD value when that study is complete and results published.

* Tier 3 - TP
	+ The lower of a) the two LCLs calculated for Tier 2 (see above) or b) TP removal using the LCL for TSS, a PP:TP ratio of 0.75, and calculated from Eq. 1 ([see below](https://stormwater.pca.state.mn.us/index.php?title=TP_and_TSS_credits_and_guidance_for_manufactured_treatment_devices_(mtds)#How_does_total_phosphorus_removal_correlate_with_concentrations_of_TSS_and_the_distribution_of_particulate_and_dissolved_phosphorus_in_runoff.3F)), if it exceeds 60%, plus specific design, construction, operation, maintenance, and assessment requirements described for the mtd device in the Minnesota Stormwater Manual. See the applicable mtd [in this section of the manual](https://stormwater.pca.state.mn.us/index.php?title=TP_and_TSS_credits_and_guidance_for_manufactured_treatment_devices_(mtds)#Derivation_of_TP_and_TSS_credits_for_specific_mtds).
	+ A 10% credit for dissolved phosphorus (DP) removal in addition to the Tier 2 credit if the device has [an MPCA-approved mechanism for permanently retaining dissolved phosphorus](https://stormwater.pca.state.mn.us/index.php?title=MPCA-approved_mechanisms_and_values_for_removal_of_dissolved_phosphorus_from_stormwater_runoff) other than volume retention. The MPCA retains discretion at assigning higher or lower removal values for a specific device for DP based on available data.
	+ A TP credit of 100% for runoff permanently retained by the device plus the Tier 2 credit for runoff not retained. See [***Protocol for assigning credits for phosphorus and total suspended solids (TSS) for manufactured treatment devices***](https://stormwater.pca.state.mn.us/index.php?title=File:Protocol_for_assigning_credits_for_phosphorus_and_TSS_for_manufactured_treatment_devices_v_1.docx) for an example calculation. At this time, the only volume retention mechanism credited is infiltration into the underlying subsoil. Infiltration must be calculated as an average annual volume infiltrated using a method approved by the MPCA.
	+ Conditions for receiving credit:
		- Must meet Tier 1 and Tier 2 conditions
		- Must meet any additional requirements for the applicable mtd defined [in this section of the manual](https://stormwater.pca.state.mn.us/index.php?title=TP_and_TSS_credits_and_guidance_for_manufactured_treatment_devices_(mtds)#Derivation_of_TP_and_TSS_credits_for_specific_mtds).