

Guidance for Evaluating Stormwater Best Management Practices

Virginia Technology Assessment Protocol (VTAP)

Prepared by:

Virginia Department of Conservation and Recreation

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<http://www.vwrrc.vt.edu/swc>

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Acronyms and Abbreviations Used in this Document

APHA – American Public Health Association
ASCE – American Society of Civil Engineers
ASME – American Society of Mechanical Engineers
ASTM – American Society for Testing and Materials
AWWA – American Water Works Association
BMP – best management practice
BOD – biochemical oxygen demand
C – Celsius
CAD – computer-aided design
CD – compact disc
cfs – cubic feet per second
Clearinghouse – Virginia Stormwater BMP Clearinghouse
COD – chemical oxygen demand
CUD – Conditional Use Designation
D₅₀ – mass median particle diameter (µm)
DCR – Virginia Department of Conservation and Recreation
DQA – data quality assessment
DQI – data quality indicator
DQO – data quality objective
e.g. – Latin *exempli gratia*, “for example”
EMC – event mean concentration
EPA – United States Environmental Protection Agency
ER – efficiency ratio
etc. – Latin *et cetera*, “and so forth”
ETV – Environmental Technology Verification
ft./sec. – feet per second
ft.³ – cubic feet
ft.³/sec. – cubic feet per second
GIS – geographic information system
GUD – General Use Designation
GULD – General Use Level Designation
HASP – health and safety plan
HDPE – high-density polyethylene
ICP/MS – inductively coupled plasma/mass spectrometry
i.e. – Latin *id est*, “that is”
in. – inches
in./hr. – inches per hour
Inc. – Incorporated
IR – infrared
mg – milligram (one thousandth of a gram)
mg/L – milligrams per liter
mL – milliliter (one thousandth of a liter)
mm/L – millimeter per liter
MQO – measurement quality objective
MS/MSD – matrix spike/matrix spike duplicate
MTD – manufactured treatment device

μm – micron or micrometer (one millionth of a meter)
N – nitrogen
NA – not applicable
NELAC – National Environmental Laboratory Accreditation Conference
NJ – New Jersey
NJCAT – New Jersey Corporation for Advanced Technology
NJDEP – New Jersey Department of Environmental Protection
NOAA – National Oceanic and Atmospheric Administration
NPDES – National Pollutant Discharge Elimination System
NRCS – Natural Resources Conservation Service
NSQD – National Stormwater Quality Database
NTIS – National Technical Information Service
O&M – operation and maintenance
PAH – polycyclic aromatic hydrocarbons
PE – professional engineer
PLD – Pilot Level Designation
PM – particulate matter
PP – particulate phosphorus
PR – pollutant removal
PSD – particle-size distribution
PSEP – Puget Sound Estuary Program
PUD – Pilot Use Designation
QA – quality assurance
QAPP – quality assurance project plan
QC – quality control
SOL – summation of loads
SM – Standard Methods
SRP – soluble reactive phosphorus
SSC – suspended sediment concentration
SUP – soluble unreactive phosphorus
TAPE – Technology Assessment Protocol – Ecology
TARP – Technology Acceptance Reciprocity Partnership
TDS – total dissolved solids
TER – technology evaluation report
TKN – total Kjeldahl nitrogen
TMDL – Total Maximum Daily Load
TN – total nitrogen
TNI – The NELAC Institute
TOC – total organic carbon
TP – total phosphorus
TPH – total petroleum hydrocarbons
TRC – Technical Review Committee
TSP – total soluble phosphorus
TSS – total suspended solids
U.S. EPA – United States Environmental Protection Agency
USGS – United States Geological Survey
VELAP – Virginia Environmental Laboratory Accreditation Program
 V_{Et_v} – Equal Volume – Variable Time
VSMP – Virginia Stormwater Management Program
VTAP – Virginia Technology Assessment Protocol
 V_{Vt_v} – Variable Volume – Variable Time

VWRRC – Virginia Water Resources Research Center
WA – Washington
WEF – Water Environment Federation
WQV – water quality volume
WSDOE – Washington State Department of Ecology

DRAFT

1 -- Introduction

The Virginia Department of Conservation and Recreation (DCR) evaluates and approves new best management practices (BMPs) and design modifications to existing BMPs. Methods under consideration or approved by DCR are listed on the Virginia Stormwater BMP Clearinghouse: <http://www.vwrrc.vt.edu/swc>. This document, the *Virginia Technology Assessment Protocol* (VTAP), describes the assessment process for listing stormwater BMPs on the Clearinghouse.

Virginia DCR also has available online the *Virginia Stormwater Management Handbook* (http://www.dcr.virginia.gov/soil_and_water/stormwat.shtml; <http://www.vwrrc.vt.edu/swc/>). The handbook provides information for stormwater management programs regarding basic hydrology and hydraulics, stormwater best management practice selection and pollution removal efficiencies, and administrative guidelines to support compliance with state stormwater regulations. A link to the handbook as well as additional information can be found on the Clearinghouse: <http://www.vwrrc.vt.edu/swc>.

1.1 -- Authority

Virginia's stormwater management programs are implemented according to the Virginia Stormwater Management Law and Virginia Stormwater Management Regulations. The law is codified at Title 10.1, Chapter 6, Article 1.1 of the *Code of Virginia*, and the regulations are found at Section 4VAC50-60 of the *Virginia Administrative Code*. The Law provides authority for the Virginia Soil and Water Conservation Board to “. . . establish minimum design criteria for measures to control nonpoint source pollution and localized flooding . . .” (§10.1-603.4 2) and to “. . . [delegate to the Department (sic DCR) . . . any of the powers and duties vested in it by [the law] . . .” (§10.1-603.2:1.2). By extension, DCR thus maintains the authority to establish, approve and update standards and specifications of the best management practices (BMPs) that may be used within Virginia to control stormwater runoff.

Because treatment technologies are evolving rapidly, the DCR needs to be able to make changes to BMP standards and add new practices as new information becomes available. For this reason, DCR has partnered with the Virginia Water Resources Research Center (VWRRRC) to establish the Virginia Stormwater BMP Clearinghouse Committee (Clearinghouse Committee). DCR staff and members of the Clearinghouse Committee have worked together to develop and design the Virginia Stormwater BMP Clearinghouse. The Clearinghouse (<http://www.vwrrc.vt.edu/swc/>) is where the approved list of BMPs – both public domain practices and manufactured treatment devices (MTDs) – and their associated standards and specifications are found. This guidance document shall be used to evaluate stormwater BMPs for certification in Virginia. The approved removal efficiencies will be the ones that state agencies and local stormwater management programs will recognize and approve when the BMPs are used in specific stormwater management plans.

1.2 -- Purpose of Virginia Technology Assessment Protocol (VTAP)

The purpose of VTAP is to:

1. Define the structure and procedures to follow for approving and listing stormwater BMPs on the Virginia Stormwater BMP Clearinghouse.
2. Establish minimum monitoring guidelines and methods for evaluating and reporting on the appropriate uses of BMPs for stormwater management.

The protocol is intended for use in assessing post-construction BMPs. It is to be utilized in the assessment of new BMPs, including manufactured treatment devices (MTDs), and modifications to existing BMPs, manufactured or otherwise, seeking credit for TP removal; assessments are not required for non-proprietary BMPs listed in Table 4.1 on the Virginia Stormwater BMP Clearinghouse (<http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html>).

DCR and the Clearinghouse Committee support the Technology Acceptance Reciprocity Partnership (TARP) and thus the *TARP Protocol for Stormwater Best Management Practice Demonstrations* (2003; see the “TARP Protocol” section below). Use of the TARP Protocol, however, does not eliminate state review or approval of projects proposing to use TARP-certified stormwater management technologies, nor does it require Virginia to “rubber stamp” the approval or certification of another state. Those seeking reciprocal certification from Virginia of practices and methods previously certified by another state must still demonstrate consistency with the procedures articulated in this document.

The VTAP is an extension of the TARP Protocol and is specific to Virginia, which has established total phosphorus load limits. The VTAP defines a testing protocol and process for evaluating and reporting on the performance and appropriate uses of BMPs that address post-construction stormwater runoff.

By obtaining accurate and relevant data, evaluators can assess performance claims and make informed decisions whether or not to approve BMPs for use in Virginia. Information acquired during testing may also be useful for the development and implementation of Total Maximum Daily Loads (TMDLs). Local governments statewide can apply the use-level designations listed on the Clearinghouse to evaluate the suitability of these BMPs for use in their communities.

TARP Protocol

For technology evaluations following the elements of the TARP Protocol, the state partners in California, Massachusetts, Maryland, New Jersey, Pennsylvania, and Virginia have agreed to:

1. Address technology review and approval barriers in policy and regulations that do not advance knowledge of a technology's performance or recognize innovative approaches to meet environmental protection goals;
2. Accept the performance tests and data, and acknowledge the approval results of a partner's review of a technology demonstration, as appropriate, in order to reduce subsequent review and approval time;
3. Increase expertise in the applications and advantages of technologies that may have superior environmental and economic benefits for controlling stormwater pollution;
4. Use the TARP Protocol, as appropriate, for state-led initiatives, grants, and verification or certification programs where the objective is to document performance efficiency and cost of best management practices;
5. Share technology information with potential users in the public and private sectors using existing state supported programs; and
6. Monitor and evaluate the results of using the TARP Protocol, and periodically review and revise the Protocol to maintain its viability.

The TARP Protocol describes a set of uniform criteria acceptable to the endorsing states. However, specific state requirements must be considered when applying for certification or verification of a stormwater BMP in a particular state. Each partner reserves the right to evaluate any application and request specific information in order to satisfy an individual state's requirements.

1.3 -- Applicability

This testing protocol is intended for detention, flow-based (volume and peak rate) stormwater BMPs and may not be suitable for all stormwater treatment practices. The protocol is NOT for use in the evaluation of erosion and sediment control technologies or products.

The assessment protocol deals with stormwater BMPs that are designed for (1) reducing stormwater runoff volume, (2) reducing peak runoff rate, and/or (3) reducing total phosphorus (TP). Devices and technologies designed to remove pollutants other than phosphorus from stormwater runoff (e.g., nitrogen, oil/grease/hydrocarbons, metals, bacteria, etc.) will not be certified in Virginia at this time. Pollutants other than phosphorus that are removed may be included in the standards and specifications posted on the Clearinghouse Website, but these removal efficiencies are not certified. Links to information about stormwater BMPs approved in other states for the removal of pollutants other than phosphorus will be provided on the Clearinghouse.

This protocol is not intended for conducting research on experimental BMPs. Technologies with limited data will only be evaluated for the **Pilot Use Designation (PUD)**. The DCR will not consider an application for a **Conditional Use Designation (CUD)** or a **General Use Designation (GUD)** unless the application includes sufficient performance data that clearly demonstrate acceptable feasibility and the likelihood that the BMP will achieve desired performance levels using the manufacturer's recommended sizing criteria, pretreatment requirements, and maintenance schedule.

1.4 -- Roles and Responsibilities

1.4.1 -- Virginia Department of Conservation and Recreation (DCR)

The Virginia Department of Conservation and Recreation is responsible for the Stormwater Management Programs in Virginia (see **Section 1.1 -- Authority**). For this reason, the DCR may obtain recommendations from outside evaluators and the Clearinghouse Committee, but the DCR is ultimately responsible for granting or denying use designations.

The Department of Conservation and Recreation:

- Grants use-level designations;
- Approves changes made to use-level designations;
- Reviews and approves Quality Assurance Project Plans (QAPPs);
- Provides oversight and analysis of all submittals to ensure consistency with the DCR's stormwater management requirements;
- Assumes the duties of the contracted evaluators (see below) when necessary; and
- Reviews new information and updates the VTAP as needed.

1.4.2 -- DCR's Evaluators

The DCR may contract with a qualified and independent individual or entity or may use internal staff to assist with the assessment process.

DCR's evaluators:

- Review applications for completeness;
- Review Quality Assurance Project Plans (QAPPs);
- Provide recommendations to the DCR for approval or denial of QAPPs;
- Periodically inspect laboratory testing and/or field testing;
- Validate monitoring data and write validation reports;
- Review technology evaluation reports (TERs) for completeness and conformance with Clearinghouse procedures and protocols;
- Provide recommendations to the Clearinghouse Committee and DCR regarding the need for additional testing (if necessary) and limitations of the technology.
- Provide recommendations and assessments to the Clearinghouse Committee and DCR regarding pollution removal efficiencies to assign to BMPs and whether or not to certify/approve BMPs at requested use designation levels; and
- Review and provide information about the technology to DCR and the Clearinghouse Committee to be included on the Clearinghouse.

1.4.3 -- Clearinghouse Committee

The Virginia Stormwater BMP Clearinghouse Committee will review applications and TERs and provide recommendations to the DCR. Members of the committee will also have the opportunity to comment on QAPPs. The reviewers represent both academics and practitioners that have experience with stormwater BMPs but are not affiliated with the proponent of the technology or other stormwater BMP manufacturers/vendors.

The Clearinghouse Committee:

- Interacts with the DCR staff to assess how well the VTAP process satisfies the DCR's stormwater treatment BMP selection objectives;
- Meets quarterly to provide oversight review of use-level-designation applications and technology engineering reports; and
- Provides recommendations and assessments to the DCR regarding pollution removal efficiencies to assign to BMPs and whether or not to certify/approve BMPs at requested use designation levels.

1.4.4 -- Virginia Water Resources Research Center

The Virginia Water Resources Research Center facilitates the VTAP review process by coordinating with the DCR and the Clearinghouse Committee.

The Virginia Water Resources Research Center:

- Develops and maintains the Virginia Stormwater BMP Clearinghouse under the direction of the DCR and the Clearinghouse Committee; and
- May facilitate outside research and evaluations, when requested, by coordinating with stormwater BMP designers, regulators, researchers, and manufacturers regarding the scientific review of existing BMP test data or new monitoring and testing.

1.4.5 -- Proponent of Technology

The proponent of the technology refers to the person/company that is promoting the project through the VTAP process. The proponent can be the manufacturer, the product vendor, consultant, etc.

The proponent:

- Submits the use-level designation application;
- Submits QAPPs for all laboratory and field testing;
- Informs the DCR of changes in the QAPP, production, manufacturer standing, key personnel, etc.;
- Submits status reports; and
- Submits the technical evaluation report (TER).

1.4.6 -- Proponent's Technical Advisor

The proponent's technical advisor provides oversight of performance testing. The DCR requires the use of a technical advisor at the onset of testing. This technical advisor is paid for by the proponent of the technology and is not provided by the DCR, the DCR's contracted evaluators, the Clearinghouse Committee, or the VWRRC.

At a minimum, the technical advisor:

- Reviews and approves the QAPPs for all testing (laboratory and field);
- Provides oversight of QAPP implementation by periodically providing inspections of test/site conditions, sampling equipment, sample handling, etc.; and
- Validates monitoring data and writes validation report.

1.5 -- Protocol Limitations, Release of Liability, and Disclosure

This protocol has been published for the purpose of evaluating or generating performance claim data for best management practices for certification in Virginia for stormwater management. Neither the DCR; its contracted partners, including the VWRRC; nor the Clearinghouse Committee accept responsibility or liability for performance of stormwater technologies being evaluated using the VTAP.

2 -- BMP Performance Goals

2.1 -- Stormwater Runoff Volume Reduction

Runoff volume reduction is defined as the total volume of rainfall and runoff reduced through canopy interception, soil infiltration, evaporation, rainfall harvesting, engineered infiltration, extended filtration or evapotranspiration at small sites. Stormwater management experts throughout the United States, participating in a panel of experts for the National Academies of Science during 2007-2008 recommended that stormwater managers change strategies for reducing pollution. Instead of relying simply on the various treatment processes employed in stormwater BMPs, we should focus our compliance criteria on reducing the volume of runoff. In response, the Virginia DCR has incorporated the **Runoff Reduction Methodology** as part of the Virginia Stormwater Management Program (VSMP) Permit Regulations. The intent of Virginia's Runoff Reduction Methodology is to (1) reduce the total volume of runoff carrying pollutants, and (2) to maintain predevelopment hydrology.

Pollution treatment is defined as the change in pollution concentration in runoff due to the treatment processes the practice incorporates. The **total pollutant load** removed by a practice is the product of the runoff volume reduction and the reduction achieved by the practice's treatment process(es). Virginia's new approach to water quality protection will, in fact, provide for enhanced pollution reduction as runoff volume is reduced and, in the process, accomplish a significant amount of groundwater recharge using the same BMPs.

Stormwater BMPs for which the proponents desire to receive certification for runoff volume reduction must demonstrate the percentage of the total runoff flowing into the BMP that is removed from the flow prior to runoff exiting the BMP. Proponents must also demonstrate whether that removed flow is (1) permanently removed from the surface discharge (e.g., through infiltration into a stone base or soil beneath the BMP), (2) shunted aside temporarily for slower discharge following the storm event, or (3) is subject to some other specified process. Limitations of the BMP must be disclosed. For example, if site constraints prevent the use of the BMP in the Tidewater or karst regions of Virginia, this limitation must be stated.

Underground storage devices that provide only void space for water storage do not need to undergo the assessment process. If a BMP is used to reduce water volume and/or improve water quality by seeking a pollutant removal certification, however, it will need to undergo the assessment process.

2.2 -- Stormwater Runoff Peak Rate Control

Peak rate control is defined as the process of controlling or reducing the maximum discharge of stormwater runoff from a drainage area. Methods to achieve this goal generally assume that the stormwater runoff is channelized and/or concentrated into a conveyance system. In other words, the hydrologic model assumes a single point of discharge for the drainage area. Peak rate control is then achieved by providing an outlet structure designed to limit the flow, and a storage volume sized to detain the developed condition runoff volume.

Although the hydraulics of storing water and restricting the rate of release tend to be non-proprietary, the use of innovative materials, configurations, trash and debris control devices, or

other components for achieving the goals of stormwater runoff peak rate control may be subject to testing for certification in Virginia. In order to evaluate such manufactured devices or designs, it is necessary for proponents to provide design information on the storage volume component -- such as underground vaults, chambers, or other vessels for storing runoff -- and the outlet control. Additional information must adequately cover long-term operation and maintenance, longevity of materials, and possible unforeseen negative consequences of installing such devices.

2.3 -- Stormwater Runoff Quality Control

2.3.1 -- Total Phosphorus (TP) Treatment

The water quality regulatory criterion in VSMP Regulations (4VAC 50-60-63) is aimed at removal of Total Phosphorus (TP). These criteria provide the basis for testing for Virginia certification.

2.3.2 -- Total Suspended Solids (TSS) and Suspended Sediment Concentration (SSC) Treatment

DCR has not established water quality regulatory criteria pertaining to the removal of total suspended solids (TSS) or suspended sediment concentration (SSC) from stormwater runoff. Although BMPs are not certified for TSS or SSC in Virginia at this time, the Clearinghouse will provide web links to information about BMPs approved for TSS or SSC in other states. For a limited time, TP certification at the **PUD** or **CUD** level may be awarded in Virginia for stormwater BMPs that have been based on TSS or SSC data if the submitted data are considered valid (Starting July 1, 2014, only TP data will be accepted for **CUD** certification).

3 -- BMP Certification Designations

Use designations are based on the quality and quantity of performance data and other information that the proponent supplies. There are three use designations for assessed stormwater BMPs in Virginia: **Pilot Use Designation (PUD)**, **Conditional Use Designation (CUD)**, and **General Use Designation (GUD)**. The goal for the proponent is to obtain a **GUD**, whereby the technology may be marketed throughout Virginia, subject to conditions that the DCR may apply as a result of the testing and assessment of the practice. BMPs may not be installed in Virginia for stormwater runoff quality control credit (i.e., phosphorus removal) unless the DCR grants it the status of **PUD**, **CUD**, or **GUD** (This rule does not apply to post-construction, non-proprietary BMPs listed in Table 4.1 of the Clearinghouse: <http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html>). Table 3.1 summarizes the testing requirements that must be met to receive each certification level. Table 3.2 provides information on the number of installations allowed in Virginia and the performance credit given once certification is awarded. An installation refers to a single unit of the BMP (Installation shall not be construed to mean multiple units of the BMP for a given project or development site.).

Table 3.1. Summary of the testing requirements for stormwater BMPs to receive Pilot Use Designation (PUD), Conditional Use Designation (CUD), and General Use Designation (GUD) in Virginia

Use-Level Designation	Minimum Testing Required to Receive Designation	Test Parameter Required to Receive TP Certification	Accepted Protocols
PUD	1 Full-scale Lab or Field	TP or TSS or SSC	Lab: NJCAT or other protocol accepted by DCR evaluator(s) Field: VTAP, NJ TARP, TAPE or other protocol accepted by DCR evaluator(s)
CUD	2 Field	TP or TSS or SSC (TSS or SSC accepted only until July 1, 2014)	VTAP, NJ TARP, TAPE or other protocol accepted by DCR evaluator(s)
GUD	2 Field	TP	VTAP

Table 3.2. Summary of the number of installations allowed in Virginia and performance credit provided for stormwater BMPs certified in Virginia at the Pilot Use Designation (PUD), Conditional Use Designation (CUD), and General Use Designation (GUD)

Certification Level	Maximum Number of Installations* Allowed in Virginia	Assumed TP Performance Credit
PUD	20	Variable (≥ 20%)
CUD	40 (total includes any PUD installations)	Variable (≥ 20%)
GUD	No Limit (Restrictions may apply)	Based on Field Test Results

* Installation refers to a single unit of the BMP.

For the assessment of the BMP, the developed QAPP for each field test site is needed and must be submitted to DCR for review and approval. The use of testing data collected in other states is allowed for assessment by the DCR. However, any field data to be included in the assessment process must be derived from testing sites representative of the urban stormwater conditions expected in Virginia (Table 3.3). For example, any product verification in a rainfall distribution other than Type II, such as those approved in Washington’s TAPE program must address the influence of the rainfall intensity, duration, peak flow, etc. Thus, a flow based system that is designed to treat the water quality flow rate would have to be sized for the Type II intensity – rather than the much lower Type IA of the Pacific Northwest. Information provided in the use-designation application, QAPP, and/or TER about the demonstration site will be used to help assess how well the site represents conditions in Virginia.

Table 3.3. Urban stormwater test conditions for certification in Virginia

Condition Influencing Stormwater	Test Conditions
Precipitation	Type II Distribution (Distribution obtained at NOAA Atlas 14)
Temperature	26.0°F-86.1°F Long-term Monthly Average 44.6 °F-66.7°F Long-term Annual Average (From Virginia State Climatology Office: http://climate.virginia.edu/virginia_climate.htm)

3.1 -- Pilot Use Designation (PUD)

The **Pilot Use Designation (PUD)** allows limited use of stormwater BMPs for the purpose of collecting field performance data according to the VTAP when the performance data do not meet the standards of applying for **CUD** or **GUD**. A **PUD** certification for phosphorus treatment may be granted for BMPs that were tested for TSS or SSC removal in the laboratory at full-scale size using Sil-Co-Sil 106. To receive a **PUD**, laboratory testing needs to follow the NJCAT

protocol or other laboratory protocol accepted by the DCR evaluators, and field testing needs to follow the VTAP, NJ TARP, TAPE or other established protocol accepted by the DCR evaluators. Because stormwater BMPs will be assigned pollutant removal efficiencies based upon the resulting verified data, there is no specified TP, TSS, or SSC removal level required by DCR for phosphorus treatment at the **PUD** certification level.

The DCR's evaluators (contracted and/or internal staff) and the Clearinghouse Committee will review all **PUD** applications and make recommendations to the DCR. The DCR will grant a **PUD** certification if it believes the practice has merit and should have field performance testing conducted.

BMPs with **PUD** certification will be listed as such on the Clearinghouse. The DCR may impose conditions for installations in Virginia. During the testing period, DCR will limit the number of installations of **PUD** BMPs in Virginia to a maximum of 20, with each BMP unit representing one installation. In addition, the proponent of the technology must notify DCR of all installation sites in Virginia. Before initiating performance testing, the proponent must receive approval from the DCR for its QAPP. Testing is required at two field sites to move to either the **CUD** or **GUD** levels.

Stormwater BMPs certified at the **PUD** level for stormwater runoff quality control will be granted an initial assumed TP performance credit ($\geq 20\%$) based on the evidence from prior testing. **PUD** certification allows for up to 20 installations in Virginia, after which the practice may not be installed in Virginia until monitoring has been completed, and the BMP has been approved. Once the proponent evaluates the data, the proponent has three options: (1) submit a technical evaluation report (TER); (2) conduct additional testing; or (3) cancel the certification request. No additional installations are allowed until the TER is approved by DCR and a **CUD** or **GUD** is granted. At the end of the test period, the test results from the field sites will be used to determine a TP removal credit.

The proponent of a poor performing **PUD** technology is not required to remove BMPs installed in Virginia.

3.2 -- Conditional Use Designation (CUD)

The **Conditional Use Designation (CUD)** is for BMPs that have undergone rigorous testing. Proponents of BMPs with data from two or more field test sites may choose to submit a **CUD** application. Proponents seeking **CUD** certification for total phosphorus treatment should have field performance data showing TP, TSS, and/or SSC removal (Starting July 1, 2014, only TP data will be accepted for **CUD** certification). To receive a **CUD**, field testing needs to follow the VTAP, NJ TARP, TAPE or other established protocol accepted by the DCR evaluators. The **CUD** certification should be sought when data are insufficient to adequately evaluate performance claims under urban stormwater conditions in Virginia and/or the data were not collected in a manner consistent with the VTAP protocol.

The DCR's evaluators (contracted and/or internal staff) and the Clearinghouse Committee will review all **CUD** applications and make recommendations to the DCR. The DCR will grant a **CUD** certification if it believes the practice has merit and should have more field performance testing conducted. The DCR grants **CUD** certifications based on submission of sufficient performance data, the recommendations from its evaluators and the Clearinghouse Committee, and

comments received from peer reviewers. BMPs with **CUD** certification will be listed on the Clearinghouse. Proponents of technologies not granted a **CUD** may request to have their BMP immediately considered at the **PUD** level (**PUD** review fees waived) or resubmit the application at a later date at the **CUD** level (and pay all associated **CUD** review fees).

Technologies granted a **CUD** certification by the DCR are allowed to be installed in Virginia while more extensive field testing occurs. Proponents of **CUD** technologies must submit a QAPP for each test site and cannot begin performance testing until the QAPP is approved.

The DCR may impose conditions for installations in Virginia. DCR will limit the number of installations of **CUD** BMPs in Virginia to a maximum of 40, with each BMP unit representing one installation. BMPs installed in Virginia under the **PUD** certification count towards this maximum. Testing is not required at all installations, but the proponent of the technology must notify DCR of all installation sites in Virginia. Testing is required at two distinct field sites for certification at the **GUD** level.

BMPs certified at the **CUD** level for stormwater runoff quality control will be granted an initial assumed TP performance credit ($\geq 20\%$) based on the evidence from prior testing. **CUD** certification allows for up to 40 installations of the BMP in Virginia, after which the practice may not be installed in Virginia until monitoring has been completed, and the BMP has been approved. Once the proponent evaluates the data, the proponent has three options: (1) submit a technical evaluation report (TER); (2) conduct additional testing; or (3) cancel the certification request. At the completion of the test period, the test results from the field sites will be used to determine a TP removal credit.

Until July 1, 2014, applications that show a reliable 80% removal or greater of TSS or SSC using field data will be granted a reciprocal TP credit of 25% removal at the **CUD** level until field testing is performed for TP removal and BMP specific results are obtained. TP removal for the **General Use Designation** will be based on the results of performance field testing of TP, not TSS or SSC data.

The proponent of a poor performing **CUD** technology is not required to remove BMPs installed in Virginia.

3.3 -- General Use Designation (GUD)

The **General Use Designation (GUD)** confers a general acceptance for the stormwater BMP based on validated field performance claims. At a minimum, a product should have a substantial data set that verifies

- sizing for the land use type that was monitored -- specific treatment flow rate (cfs per square foot of filter media if a filtering device, or surface area of treatment chamber if a settling device) or volume capture;
- treatment performance (qualified by testing minimum and maximum influent loads, etc.);
- maintenance requirements and frequency of maintenance; and
- longevity for typical urban conditions in Virginia.

To obtain a **GUD** certification for stormwater runoff quality control, field testing for TP removal is required. The testing and evaluation must conform to the requirements in the VTAP and represent application conditions expected in Virginia.

BMPs seeking a **GUD** certification must have been field tested in at least two field sites that are representative of urban stormwater runoff in Virginia. The easiest way to ensure that the testing occurs under the required conditions is to pick field test sites located in Virginia. When including test sites outside of Virginia, the proponent must show that the site will represent conditions commonly expected in Virginia (Table 3.3). Typical weather must be characterized by similar rainfall patterns, such as Type II rainfall. Information provided in the use-designation application, QAPP, and/or TER about the stormwater BMP demonstration site will be used to assess how well the site represents conditions in Virginia. For the assessment of the BMP, the developed QAPP for each test site, whether located within or outside of Virginia, is needed and thus must be submitted to DCR for review and approval.

To apply for the **GUD** certification, the proponent of the technology submits a **GUD** application, complete with QAPPs for the field test sites and TER, to the DCR. The DCR's evaluators (contracted and/or internal staff) and the Clearinghouse Committee will recommend to the DCR that a **GUD** certification be granted if they find the performance claims to be validated. The DCR grants **GUD** certifications for technologies based on submission of sufficient performance data, the recommendations from its evaluators and the Clearinghouse Committee, and comments received from peer reviewers. Proponents of technologies not granted a **GUD** may specify to have their BMP immediately considered either at the **PUD** or **CUD** level (**PUD** or **CUD** review fees waived, respectively) or resubmit the application at a later date at the **GUD** level (and pay all associated **GUD** review fees).

BMPs with **GUD** certification will be listed as such on the Clearinghouse. Technologies with a **GUD** certification from the DCR may be used anywhere in Virginia, subject to conditions the DCR may apply as a result of the testing and evaluation of the practice. Technologies that receive a **GUD** certification have no expiration date. If at a later date, it is discovered that a **GUD** certified technology is not performing at the level of the approved performance claim, the practice will be removed from the Clearinghouse until revisited so that either the design criteria are improved to achieve the listed performance or the performance claim is corrected.

4 -- Assessment Process

The Virginia Stormwater BMP Clearinghouse will maintain a list of approved BMPs on the Clearinghouse to assist local jurisdictions in identifying stormwater technologies and products. Technologies undergoing testing to meet criteria of the **General Use Designation (GUD)** may be listed on the Clearinghouse with either a **Pilot Use Designation (PUD)** or a **Conditional Use Designation (CUD)**. Special restrictions apply to technologies with a **PUD** or **CUD** (refer to **Section 3 -- BMP Certification Designations**).

4.1 -- Overview of Virginia Technology Assessment Protocol

The assessment process in Virginia begins when the proponent submits a **PUD, CUD, or GUD** application package to DCR. An application fee, see Table 4.1, is due at the time of submittal (checks should be made payable to “Treasurer of Virginia”). Figure 4.1 illustrates the overall certification process in Virginia for stormwater BMPs. Submitted applications are reviewed for completeness, and if complete, the DCR’s evaluators (contracted or internal staff) will assess the application package and propose a use designation. If recommended by the DCR’s evaluators, the technical evaluation report (TER), submitted as part of the application package, will be included on the Clearinghouse for peer review and comment. The DCR’s evaluators will respond to the public comments and present their recommendations to the Clearinghouse Committee. The Clearinghouse Committee will review the application package, recommendations made by DCR’s evaluators, and public comments. The Clearinghouse Committee will develop a use designation recommendation and notify the proponent and the DCR of the recommendation. The DCR will review all recommendations and determine an appropriate use designation. Certified technologies will be included on the Clearinghouse.

Table 4.1. Application and review fees for stormwater BMPs seeking certification in Virginia

Type of Review	Fee
Application Review	
PUD	\$ 20,000*
CUD	\$ 40,000*
GUD	\$ 40,000*
Re-submittal fee	\$ TBD

* To be determined (TBD) based on the values established per the state procurement process.

Technologies that do not meet the **GUD** criteria may be listed on the Clearinghouse as either a **PUD** or a **CUD**. Once a **PUD** or **CUD** has been awarded, the proponent must provide quarterly status reports to the DCR. Proponents of technologies with certifications at the **PUD** or **CUD** level must have a technical advisor to review and approve the QAPP. The QAPP then needs to be submitted to and approved by the DCR. Even if the testing site is located outside the state of Virginia, QAPPs are required for Virginia certification. The QAPP will be reviewed by DCR’s evaluators; the members of the Clearinghouse Committee will have the opportunity to comment on the QAPP. DCR will review all recommendations and approve or disapprove the QAPPs.

Proponents may not begin performance testing until the DCR has approved the QAPP. If the QAPP is disapproved by DCR, the proponent must modify and resubmit the plan. Once the QAPP is approved by DCR, field performance testing in Virginia may begin.

At the end of the testing period, the proponent of a stormwater BMP with either a **PUD** or a **CUD** submits an updated application, including a TER, to DCR. The TER is reviewed in the same manner as the initial application package (described in the first paragraph of this section). Approved technologies will be listed on the Clearinghouse. If the TER of the field-tested technology is disapproved for the **CUD** or **GUD**, the proponent will be notified of the DCR's decision and reason for it. Proponents of technologies not granted the use-level designation for which they applied may request to have their BMP immediately considered at a lower level if applicable (review fees waived) or resubmit an updated application at the initially submitted level at a later date (and pay all associated review fees).

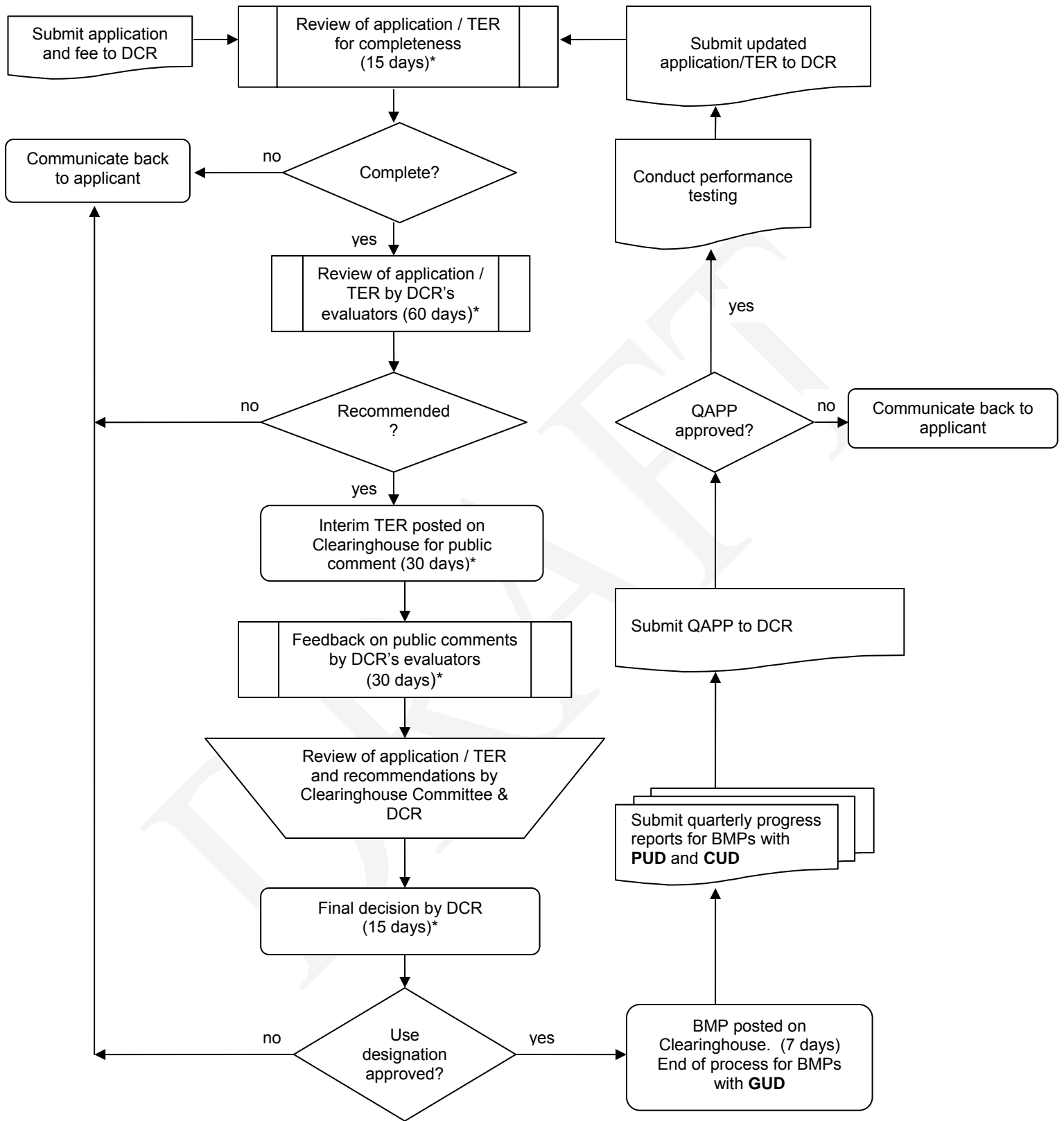


Figure 4.1. Flow chart illustrating the certification process in Virginia for stormwater BMPs

* Time period may be modified based on information obtained in the state procurement process for the DCR evaluator or other reasons; days = calendar days

4.2 -- Requesting a Use Designation

The first step for a proponent wishing to market a stormwater BMP in Virginia will be to amass the product information and certified data to determine the use designation level for which to apply. The proponent will need to ask a fundamental question:

Does the technology have field data that represent urban stormwater pollutant load and rainfall characteristics in Virginia, and do these data meet the VTAP requirements?

To determine the answer to this question, the proponent of the technology must be familiar with the VTAP as described in this document.

The following may be helpful guidance in selecting the most appropriate use designation level for which to apply:

- Proponents of BMPs with full-scale laboratory performance data and no, or limited, field testing data should submit a **PUD** application. TP, TSS, and/or SSC data can be used to receive TP certification at the **PUD** level. If TSS or SSC data from laboratory testing are reported, Sil-Co-Sil 106 should have been used.
- Proponents of BMPs with field performance data that
 - (a) were collected from at least two field sites representing urban stormwater conditions in Virginia, and
 - (b) conform to an established protocol such as NJ TARP, TAPE, or other protocol accepted by the DCR's evaluatorsshould submit a **CUD** application. BMPs seeking **CUD** status for total phosphorus treatment should have performance data showing TP removal (Until July 1, 2014, proponents may submit performance data showing TSS/SSC removal as described above to receive a **CUD**).
- Proponents of BMPs with field performance data that
 - (a) were collected from at least two field sites representing urban stormwater conditions in Virginia, and
 - (b) conform to the VTAPshould submit a **GUD** application. TP data are required to receive TP certification at the **GUD** level.

Proponents seeking a use-level designation by the DCR will need to submit an application and application fee (Table 4.1). Submit an electronic version, as a CD or E-mail attachment, to DCR. An electronic copy of quality assurance project plans, interim status reports, and other correspondences should also be provided to DCR.

The application fee and CD submissions should be mailed to DCR at the following address:

Virginia Department of Conservation and Recreation
Division of Soil and Water Conservation
Stormwater Management BMP Clearinghouse
203 Governor Street, Suite 206
Richmond, VA 23219-2094

E-mail submissions should be sent to DCR at the following address:

SWMESquestions@dcr.virginia.gov

For assistance, please contact DCR's Virginia Stormwater Management Program.

E-mail: SWMESquestions@dcr.virginia.gov

4.3 -- Assessment Timeline

The timeline below includes required deadlines in bold-type font. Failure to meet these deadlines may result in a suspension or cancellation of a designation. The remaining items provide guidelines for the amount of time expected for a given step in the process. The evaluators will review submittals as quickly as possible and will communicate with the proponent of the technology if delays or problems arise.

1. Submit application package, including the TER and appropriate fee (checks should be made to "Treasurer of Virginia").
2. Application is reviewed for completeness – Within 15 calendar days
3. If application is complete, application is reviewed by DCR's evaluators (contracted and/or internal staff) – Within 60 calendar days
4. If recommended by DCR's evaluators, interim TER is listed on the Clearinghouse for peer review – 30 calendar days
5. DCR's evaluators comment on peer reviews – 30 calendar days
6. DCR and Clearinghouse Committee review application and recommendations – The Clearinghouse Committee meets quarterly and will review applications in the order they were received. Depending on the number of applications and TERs to be reviewed, the submitted application will be assessed at the earliest possible Clearinghouse Committee meeting.
7. DCR makes final decision – Within 15 calendar days
8. Proponents of technologies not granted the use-level designation for which they applied may request to have their BMP immediately considered at a lower level if applicable (review fees waived) or resubmit an updated application at the initially submitted level at a later date (and pay all associated review fees). If approved by DCR, the BMP is listed on the Clearinghouse – Within 7 calendar days

For BMPS with approval at the **GUD** level, the process stops here. For BMPs with approval at the **PUD** or **CUD** levels, the process continues as described below:

9. Reporting time begins once granted the **PUD** or **CUD**. **Quarterly status reports are due to DCR for the preceding three-month period, specifically:**
 - **May 1st for the period January 1 – March 31;**
 - **August 1st for the period April 1 – June 30;**
 - **November 1st for the period July 1 – September 30; and**
 - **February 1st for the period October 1 – December 31.**Continue submitting progress reports until TER is submitted.
10. Submit QAPP that meets the VTAP's requirements
11. QAPP is reviewed by DCR's evaluators – Within 60 calendar days
12. QAPP reviewed by Clearinghouse Committee members and DCR. If QAPP is approved by DCR, monitor field installation.
13. Submit TER at the conclusion of testing and data analysis.
14. The TER is reviewed for completeness – Within 15 calendar days
15. If TER is complete, DCR's evaluators review the TER – Within 60 calendar days
16. If recommended by DCR's evaluators, interim TER is included on the Clearinghouse for peer review – 30 calendar days
17. DCR's evaluators review and respond to peer comments – 30 calendar days
18. Clearinghouse Committee and DCR review TER and recommendations – The Clearinghouse Committee meets quarterly and will review applications in the order they were received. Depending on the number of applications and TERs to be reviewed, the

submitted TER will be assessed at the earliest possible Clearinghouse Committee meeting.

19. Once reviewed by Clearinghouse Committee, the DCR issues a higher use-level designation, revokes the current use-level designation, or allows for continued testing at the present level – Within 15 calendar days

Failure to submit progress reports or failure to demonstrate satisfactory progress during the testing period risks suspension or cancellation of the use-level designation and possible removal from the Clearinghouse. A suspension allows no additional installations in Virginia during the suspension period. The DCR will remove the suspension when the proponent demonstrates satisfactory progress in completing the required component. A cancellation requires the proponent to resubmit an application with appropriate fee for the desired use-level designation.

4.4 -- Approval of a Quality Assurance Project Plan (QAPP)

Once approval is granted for a specific use-level designation (**PUD** or **CUD**), a quality assurance project plan (QAPP) *must be submitted to DCR and approved by DCR before* initiating performance testing. Development of the QAPPs should be a collaborative effort between the proponent of the BMP and the proponent's technical advisor. **Section 5.2 -- QAPP and Documentation** outlines the requirements of the QAPP.

The DCR will identify evaluators to review and provide recommendations concerning approval of QAPPs, and the members of the Clearinghouse Committee will have the opportunity to comment on the QAPPs. DCR will make the final decision concerning QAPP approval. The proponent should not begin performance testing until the QAPP is approved. Even if testing sites are located outside the state of Virginia, QAPPs are required for Virginia certification. If the QAPP is disapproved by DCR, the proponent must modify and resubmit the plan before beginning monitoring. Once the QAPPs are approved by DCR, field performance testing in Virginia may begin.

When a change to the QAPP is warranted, the author of the plan must amend it to document the change and submit the revised plan to the DCR for approval.

4.5 -- Requirements of Performance Testing

A QAPP must be approved by the DCR before initiating any performance testing. Performance testing must follow the procedures outlined in the approved QAPP. Performance testing should be designed to meet all requirements of the VTAP, with the goal of obtaining the **General Use Designation**. Data used in the field assessments must be derived from test sites of typical urban stormwater conditions in Virginia.

4.6 -- Granting a Use Designation

The DCR grants a use-level designation based on the information submitted and best professional judgment. Submitting the appropriate amount of data does not guarantee that the DCR will grant a use-level designation. The DCR bases decisions on the system performance and factors that influence the performance (e.g., sizing, maintenance).

Certain restrictions apply to technologies granted a **PUD** or **CUD** (refer to **Section 3.1 -- Pilot Use Designation** and **Section 3.2 -- Conditional Use Designation**). The DCR may place restrictions on the use of the technologies granted a **GUD**.

Proponents of technologies not granted a **CUD** may request to have their BMP immediately considered at the **PUD** level (**PUD** review fees waived) or resubmit the application at a later date at the **CUD** level (and pay all associated **CUD** review fees). Likewise, proponents of technologies not granted a **GUD** may specify to have their BMP immediately considered either at the **PUD** or **CUD** level (**PUD** or **CUD** review fees waived, respectively) or resubmit the application at a later date at the **GUD** level (and pay all associated **GUD** review fees).

For approved technologies, the manufacturer shall provide design standards and specifications and operation/maintenance specifications for the technology that are consistent with the accepted research findings.

5 -- Field Monitoring and Data Evaluation

The field monitoring protocol is intended for use in assessing post-construction BMPs. It is to be utilized in the assessment of new BMPs, including manufactured treatment devices (MTDs) and design modifications to existing BMPs, manufactured or otherwise. Assessments are not required for non-proprietary BMPs listed in Table 4.1 on the Virginia Stormwater BMP Clearinghouse (<http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html>).

The scope of the field monitoring and evaluation program consists of the following ten elements:

1. Monitoring Site Selection
2. Quality Assurance Project Plan (QAPP) and Documentation
3. Monitoring Program Design
4. Monitoring System Design and Installation
5. Sample Collection, Analysis, and Quality Control
6. Data Verification, Validation, and Certification
7. Data Management
8. Data Quality Assessment
9. Pollutant Removal and Efficiency Rating Methods
10. Preparation of the Technical Evaluation Report (See **Section 6.5 -- Technical Evaluation Report (TER)**)

The specific activities and requirements associated with each of the program elements are described in the following subsections.

5.1 -- Monitoring Site Selection

The success of the field monitoring program will depend in large part on locating a suitable test site. DCR requires field testing in Virginia or locations with similar field conditions in order to obtain a **GUD**; the burden of demonstrating the similarity of those conditions is on the applicant. The test sites should incorporate characteristics that are consistent with the intended applications and geographical locations for the technology. Sites should provide influent concentrations typical of stormwater for those land-use types using a consistent sampling methodology and homogenous land use.

Prospective test sites shall initially be evaluated based on engineering and institutional concerns. Engineering concerns would include hydraulic loading, hydraulic grade, types of pollutants, and area and depth limitations. Institutional concerns would include site access, security, and existing permit requirements. The sites should be well-established with no on-going land development and/or disturbance activities. The following factors should also be considered when choosing a test site:

- The contributing (up-gradient) catchment should not be served by a combined sewer system, or if it is, steps must be taken to account for the possibility that stormwater samples would be contaminated by sanitary sewage.

- The storm drain system should be sufficiently well understood to allow a reliable delineation and description of the catchment area (e.g., geographic extent, topography, soils, land uses).

5.2 -- QAPP and Documentation

Proponents must carefully plan and execute field monitoring programs. *After* obtaining a **PUD** or **CUD** and *before* initiating performance testing at a site indicative of or located in Virginia, the proponent must prepare and submit a quality assurance project plan (QAPP) and associated monitoring documents for review and approval by the DCR or its contract evaluator. The proponent's technical advisor should oversee preparation and implementation of QAPPs and associated monitoring documents and forms. Particular care must be taken to insure that field and laboratory QAPP elements are well-integrated.

5.2.1 -- Preparation of a QAPP

The QAPP must specify the procedures to be followed to ensure the validity of the test results and conclusions. A QAPP addresses the basic elements and will define and describe the following:

- Who will use the data.
- What the project goals/objectives/questions or issues are.
- What decision(s) will be made from the information obtained.
- How, when, and where project information will be acquired or generated.
- What possible problems may arise and what actions can be taken to mitigate their impact on the project.
- What type, quantity, and quality of data are specified.
- How the data will be analyzed, assessed, and reported.

The QAPP consists of four basic element groups:

- Project management.
- Data generation and acquisition.
- Assessment and oversight.
- Data validation and usability activities.

Each element group is subsequently divided into sub-elements addressing different topics. The plan must address all applicable elements found in *EPA Requirements for QA Project Plans* (EPA QA/R-5) (U.S. EPA 2001) (http://www.epa.gov/quality/qa_docs.html). If an element is not applicable, it must be so stated in the QAPP. When addressing the project management elements in *EPA Requirements for QA Project Plans* (EPA QA/R-5) (U.S. EPA 2001), be sure to:

- Include project manager, test site owner/manager, field personnel, consultant oversight participants, and analytical laboratory that will perform the sample analyses.
- Identify the proponent's technical advisor.
- Identify each study participant's roles and responsibilities.
- Provide key personnel resumes.
- Include any acquired training or certifications needed to complete the project.

- Document any certifications received from a national or state agency regulating laboratory certification or accreditation programs for each laboratory participating in the project.
- Show certification by a professional engineer (P.E.) that the structural components of BMPs are proper.
- Provide a schedule documenting when the equipment is expected to be installed, the expected field testing start date, projected field sampling completion, and final project report submittal.

The final plan should generally consider all TAPE (WSDOE 2008) and TARP (2003) requirements, be consistent with them where appropriate, and identify (as well as justify) inconsistencies.

In general, proponents shall:

- Include the following information about each test site:
 - location of the test site (street, city, state, zip);
 - site map showing catchment area, drainage system layout, and treatment device and sampling equipment locations;
 - test-site catchment area, tributary land uses, (roadway, commercial, high-use site, residential, industrial, etc.) and amount of impervious cover, topography, slope, geometry/planimetrics, and all anthropogenic/biogenic activities affecting the catchment;
 - potential pollutant sources in the catchment area (e.g., parking lots, roofs, landscaped areas, sediment sources, exterior storage, or process areas);
 - particle-size distribution of sediments in runoff (entire distribution, specify D_{50})
 - baseline-stormwater-quality information to characterize conditions at the site;
 - location of flow devices and samplers in relation to the inlets and outlets of the BMP (demonstrate that flow devices and samplers are installed and positioned properly to ensure that samples are representative of influent runoff and effluent runoff [i.e., sample the influent as close as possible to the inlet of the system and sample the total treated effluent]);
 - regional climate station for test site and its average number of storms per year, average annual precipitation (in.), and monthly average precipitation (in.)
 - drainage area flow rates (i.e., water quality design flow, 2-year, 10-year, and 100-year peak flow rates) at 15-minute and 1-hour time steps as provided by an approved continuous runoff model;
 - make, model, and capacity of the treatment device;
 - evidence of matching unit operations, and hydraulic/volumetric capacity to watershed loads,
 - analysis of rainfall-frequency distributions and their anticipated effect on the treatment unit,
 - location and description of the closest receiving water body;
 - bypass flow rates and/or flow splitter designs necessary to accommodate the treatment technology (specify the bypass flow set point);
 - pretreatment system set-up and operational details, if required by site conditions or technology operation;
 - potential adverse site conditions such as climate, tidal influence, high groundwater, rainfall pattern, steep slopes, erosion, high spill potential, illicit connections to stormwater catchment areas, and industrial runoff.
- Prepare and coordinate a QAPP and ensure that it includes:

- data quality objectives (DQOs) (Test objectives should be clear, concise, quantitative, and unambiguous, such that standardized test methods and procedures can be applied. The entire range of technology performance capabilities should be tested in order to demonstrate the full potential of the technology.) (See *Guidance on Systematic Planning Using the Data Quality Objective Process* [EPA QA/G4] [U.S. EPA 2006c] available at: http://www.epa.gov/quality/ga_docs.html);
- sampling equipment and procedures (location and frequency);
- description of how any grab samples will be collected and at what intervals they will be collected during the storm event;
- description of how composite samples will be collected (Samples collected as discrete flow composites may need to be manually composited following the sampling event. If samples will be manually composited, provide a description of the compositing procedures to prevent sample cross-contamination);
- chain-of-custody procedures;
- sample preservation/holding times;
- quality control (QC) sample protocol (splits and composites; field, trip, equipment blanks; spikes; duplicates); and
- sample equipment decontamination.
- Have field sampling overseen by the technical advisor.
- Use standardized test methods and procedures, where applicable.
- Have all analyses conducted by an independent laboratory. Use of a laboratory certified under 1 VAC 30 Chapter 45 or 1 VAC 30 Chapter 46 is required. Some constituents and procedures may not have a certification and/or accreditation (for example, particle-size distributions [PSDs]); procedures for these tests will be reviewed on a case-by-case basis by the BMP Clearinghouse and DCR.
- Use equipment manufacturer's recommended instrument calibration/certification procedures.

Standardized test methods and procedures shall be used to collect stormwater BMP data. Several sources of test plans, test methods, procedures, and standards are available for testing stormwater technologies. Some examples are provided below:

- *EPA Requirements for QA Project Plans* (EPA QA/R-5) (U.S. EPA 2001, available at http://www.epa.gov/quality/ga_docs.html).
- *National Field Manual for Collection of Water Quality Data, Techniques of Water Resources Investigations Book 9* (USGS, variously dated, available at <http://water.usgs.gov/owq/FieldManual/>).
- *National Water Quality Handbook* (NRCS 2003, available at <http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17843.wba>).
- *NPDES Storm Water Sampling Guidance Document* (EPA 833-B-92-001) (U.S. EPA 1992, available at <http://www.epa.gov/npdes/pubs/owm0093.pdf>).
- *Standard Methods for the Examination of Water & Wastewater: Centennial Edition* (American Public Health Association [APHA], the American Water Works Association [AWWA], and the Water Environment Federation [WEF] 2005).
- U.S. Environmental Protection Agency (EPA) Test Methods (analytical measurements).
- American Society for Testing and Materials (ASTM) Standards (Website: <http://www.astm.org/>).
- The National Environmental Laboratory Accreditation Conference (NELAC) Institute (TNI) (Website: <http://www.nelac-institute.org/>).

- *Caltrans Comprehensive Protocols Guidance Manual* (Stormwater Quality Monitoring Protocols) (California Department of Transportation 2003, available at <http://www.dot.ca.gov/hq/env/stormwater/pdf/CTSW-RT-03-105.pdf>).
- *Guidance Manual for Monitoring Highway Runoff Water Quality* (FHWA-EP-01-022) (Federal Highway Administration 2001, available at http://www.fhwa.dot.gov/environment/h2o_runoff/index.htm).
- *Urban Stormwater BMP Performance Monitoring* (provides general advice on selecting monitoring methods and equipment, installing and using equipment, and implementing sampling approaches and techniques; prepared under support from U.S. Environmental Protection Agency, Water Environment Research Foundation, Federal Highway Administration, Environmental and Water Resources Institute of the American Society of Civil Engineers) (Geosyntec Consultants and Wright Water Engineers, Inc. 2009, available at <http://www.bmpdatabase.org/MonitoringEval.htm>).

DCR may allow flow-controlled field test sites. Flow-controlled field test sites use actual stormwater but control the flow through BMPs where it is demonstrated that the monitored water quality is not being impacted in a way that biases testing. Sampling plans for flow controlled field sites will include measures to estimate flow and mass flux in both the treated and bypass flows.

A QAPP is required for each test site for BMPs intended to be certified for use in Virginia; whether the test site is in Virginia or not.

An electronic version, CD or E-mail attachment, of the QAPP should be mailed to the following address:

Virginia Department of Conservation and Recreation
 Division of Soil and Water Conservation
 Stormwater Management BMP Clearinghouse
 203 Governor Street, Suite 206
 Richmond, VA 23219-2094

E-mail: SWMESquestions@dcr.virginia.gov

For assistance, please contact DCR's Virginia Stormwater Management Program.

E-mail: SWMESquestions@dcr.virginia.gov

The QAPP must be kept current and thus should be reviewed annually to determine if any changes are necessary. When a change is warranted, the QAPP must be amended to document the change and submitted to the DCR for approval. Once approved by the DCR, the revised plan should be sent to all the individuals cited in the QAPP distribution list for implementation. Similarly, changes in key personnel associated with the project must be reported to DCR and all individuals cited in the QAPP distribution list.

5.2.2 -- Preparation of Monitoring Documents and Forms

Depending on test conditions, the following monitoring documents and forms shall be submitted along with the QAPP:

- **Health and Safety Plan (HASP).** A site-specific HASP must be developed for the test site(s), including confined space entry if applicable.
- **Work Permit for Confined Space.** If applicable, the field crew must fill out a “permit” for each confined space entry with names and qualifications of the personnel involved and the procedure that was followed.
- **BMP Inspection-Maintenance Log.** Following the inspection and maintenance procedures outlined in the BMP Operation and Maintenance Manual, the field crew must record the accumulation of sediment, oil, and trash in the BMP. The recorded data will be used to establish the maintenance frequency of the device.
- **Stormwater Monitoring Equipment Maintenance Log.** The field crew uses this log when performing inspection and basic maintenance of the installed monitoring equipment.
- **Sampling Event Data Sheet.** The field crew enters information into this data sheet before and after each sampling event with a variety of information including sampler pacing, sample bottle replacement, samples collected, flows, storm volumes treated and bypassed, QA/QC performed, and sample identification.
- **Chain of Custody.** This sheet tracks the sample containers and specifies how the samples will be analyzed.

5.3 -- Monitoring Program Design

The monitoring program must be designed in accordance with the procedures described in the QAPP. In the event that changes in procedures are warranted, the QAPP must be amended to document the changes, and the amendments submitted to the DCR for approval prior to implementing the revised plan.

The monitoring program should reflect the intended applications of the BMP. Samples should be collected over a range of rainfall intensities encountered during the year.

5.3.1 -- BMP Sizing Methodology for Test Sites

Proponents need to verify that the BMP can treat the runoff of 1-inch of rainfall. The proponent must submit a proposed methodology for use in selecting the size of the BMP in the test system based upon standard design criteria for the BMP, including but not limited to peak flow rate or water-quality treatment volume, drainage area, and predicted performance at that size in terms of total phosphorus load reduction. The facility sizing methodology should reflect the design basis of the device and be sufficiently generalized for all sites. The applicant should provide specific supporting calculations provided for the specific test site(s). Preliminary water quality data analysis obtained during characterization of the test site(s) can be part of the basis used

for sizing the BMP. Virginia DCR will review the methods and comment on the specific facility size/design, however, this review is for testing purposes only.

5.3.2 -- Monitoring and Sampling Parameters

The following subsections provide the protocol for data collection. It is largely based on sections selected from the *Guidance Document for Evaluating Emerging Stormwater Treatment Technologies, Technology Assessment Protocol – Ecology (TAPE)* (available at <http://www.ecy.wa.gov/biblio/0210037.html>) (WSDOE 2008) and *The Technology Acceptance Reciprocity Partnership (TARP) Protocol for Stormwater Best Management Practice Demonstrations* (TARP 2003 and NJDEP 2009).

Although there are different approaches for collecting performance data, the following protocol is considered by the DCR to be necessary for obtaining scientifically valid data, particularly for field demonstrations.

5.3.2.1 -- Qualifying Storm Event Parameters

Current weather forecasts are available on <http://weather.gov/> and should be consulted when evaluating forecasts for qualifying storm events. The following parameters must be used to define qualifying storm events:

- More than 0.1-inch of total rainfall.
- Minimum inter-event period of 6 hours, where cessation of flow from the system begins the inter-event period (storms occurring within six hours of each other are considered to be one storm).
- Flow-weighted composite samples covering a minimum of 70% of the total storm flow, including as much of the first 20% of the storm as possible, must be taken for all constituents on which removal efficiencies are to be computed.
- A minimum of 10 aliquots (i.e., 10 influent and 10 effluent aliquots) should be collected per storm event. Exception: for short duration storms, those less than one-hour in duration, 6 aliquots are the minimum. One composite sample comprised of 10 aliquots (or 6 aliquots for short duration storms) equals a water quality sample minimum. It should be noted that use of programmable automatic samplers, which is recommended, can likely result in a larger number of aliquots being taken at a finer scale through methods which are explained in **Section 5.3.2.5 -- Sampling Methodology**. This larger number of aliquots, if planned appropriately, does not increase the sampling burden of the applicant.

5.3.2.2 -- Rainfall Monitoring

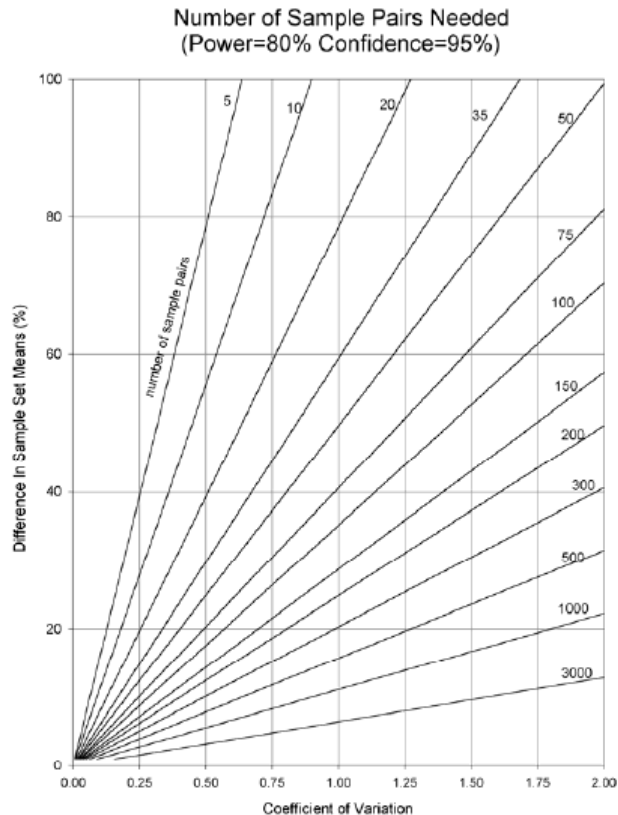
Rainfall must be recorded during each storm event at a measurement sensitivity of no greater than 0.01 inch, and a maximum intensity measurement capability of no less than 4 in./hr. Each event (defined by the measurement sensitivity) must be recorded. If the onsite rainfall monitoring equipment fails during a storm event, data from the next-closest, representative rain gauging station may be used to determine whether the event meets the qualifying storm event parameters. Clearly identify any deviations to DCR. Nearby third-party rain gauges may be used only in the event of individual rain gauge failure and only for the period of failure. If nearby rain gauges are used to fill in missing data, a regression relationship must be established with the recorded rainfall at the monitoring site, and used to compute the local (monitoring site) rainfall.

5.3.2.3 -- Flow Monitoring

Inflow to and outflow from the test unit must be measured and recorded on a continuous basis over the duration of each sampling event. The QAPP must address flow balance (e.g., for flow-through systems, provide justification if the inflow and outflow differ by more than 10%). The appropriate flow measurement method depends on the nature of the test site and the conveyance system. For offline systems or those with bypasses, flows must be measured at the bypass as well as at the inlet and outlet. Flow measurement procedures must be fully described in the QAPP and evidence of calibration provided. The flow data recording interval should be appropriate to provide adequate definition of the inflow and outflow hydrograph, but in no case should flow be logged at an interval greater than 5 minutes.

5.3.2.4 -- Minimum Number of Events Required to be Sampled

Statistical methods may be used to develop an estimate of the required sample size. Graphical plots developed by Burton and Pitt (2002) can be used to estimate sample size. The graphical plots are based on a statistically-based process known as a power analysis. The graphical plot in Figure 5.1 may be used to estimate the sample effort needed for paired testing. The methodology produces a minimum required number of samples necessary to meet a desired coefficient of variation on the order of magnitude of hundreds of storm events. However, a critical assumption of the statistical method is that events are independent, i.e., the performance of the device is not impacted by previous events, nor does current performance impact later events. Because we know that behavior of the system is, in fact, related to what occurred during prior events (due to pollutant capture and buildup), understanding the behavior of the system and its response to these events becomes critical. This influence from previous storms becomes a strong argument for requiring an increased number of samples and ultimately for sampling a relatively long continuous sequence of storm events.



**Figure 5.1. Sample Effort Needed for Paired Testing
(Power of 80% and Confidence of 95%) (source: Day, Pitt, and Parmer 1997)**

For the purposes of BMP testing under this guidance, the minimum number of events required to be sampled is set at 24. A basis for this relationship is developed in more detail in **Appendix A -- Number of Tests**. If 24 events do not cover the entire estimated maintenance cycle of the BMP, additional events must be sampled periodically until the maintenance cycle endpoint is established, and then at least one event immediately before and after maintenance must be monitored and reported.

The best assessment of performance is obtained from sampling a continuous sequence of qualifying events, or as close as possible to that goal. At a minimum, 10 storms must be sampled in sequence, and five paired storms must be sampled.

An assessment program designed in this manner will provide a more complete description of the behavior of the system by sampling the bulk of the mass flux through the system during each event and throughout the sampling campaign.

In addition, a proponent shall monitor a minimum of two events that exceed 75% of the design capacity. Also, a minimum of 15 inches of precipitation is to be monitored. The sampling and performance results for all sampled qualifying storms must be reported and included in all performance and maintenance interval computations.

5.3.2.5 -- Sampling Methodology

Sampling protocols must be fully described in the QAPP, and the approved methods adhered to throughout the study program. This subsection provides a brief discussion of sampling methods that may be applicable to BMP performance measurements.

- **Grab samples** are discrete, individual samples taken within a short period of time (usually less than 15 minutes). Grab samples should only be used for certain constituents, in accordance with accepted standard sampling protocols, and never for the purpose of computing loads, except in cases where a sequence of grab samples is collected along the hydrograph. In such cases, if instantaneous flow data are available, loads may be computed as illustrated in the schematic of Figure 5.2. Assuming that discrete samples were taken at each of the black dots situated along the hydrograph and subsequently analyzed (C_i), the total event load may be estimated as:

$$\text{Total Load} = \sum_{i=1}^9 C_i \Delta V_i$$

where ΔV_i = incremental runoff volume, L^3

C_i = constituent concentration m/L^3

The degree to which the total load estimated in the foregoing manner could be said to approach the “true” load would be increased by extracting (and analyzing) more samples at smaller (but not necessarily equal) increments of flow. Using such an approach should, in theory, eventually produce a very fine estimate of the true load of any constituent of interest if the number of samples collected was very high. There are, however, practical limits. For example, most automatic samplers have a total bottle limit of 24 to 28 samples. Using this as the upper limit of the number of samples that could be collected during an event, it may be seen that, even for constituents having modest unit analytical costs, load characterizations with the discrete sampling method could very quickly become cost-prohibitive.

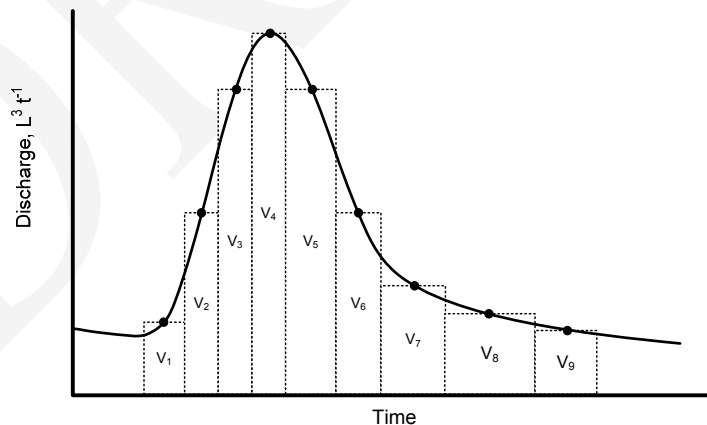


Figure 5.2. Equal volume, variable time, flow-weighted composite (Graphic courtesy of T. Grizzard)

- **Composite samples** are more often better suited to the goals of stormwater sampling or BMP performance assessments that seek to develop a total mass load or an event mean concentration (EMC) for a constituent of interest in the runoff. In such cases, it

may be more cost-effective to develop a sampling strategy around flow-weighted-composite samples of the entire runoff event. There are other strategies for constructing composite samples, but only flow-weighted composites should be considered for use. The potential for undue bias is simply too high with essentially all other methods. The flow-weighting approach is, generally, based on the premise that the volume of any sub-sample (or aliquot) in a composite is proportional to the flow increment that it represents. There are several methods for producing flow-weighted composites, but two of the most common are:

- Variable Volume – Variable Time ($V_V t_V$)
- Equal Volume – Variable Time (V_{Et_V})

Figure 5.2 may again be used to illustrate the $V_V t_V$ compositing approach. Note that there are 9 samples and 9 volumes in Figure 5.2. Assuming that V_1 is the smallest volume increment of the nine sub-samples taken, it may be used as the basis for calculating the aliquot volumes of the remaining eight sub-samples in the overall composite. For example, if the index aliquot for incremental volume V_1 is taken to be 100 mL, then the volume for the aliquot representing V_6 would be $100 \times V_6/V_1$. After all nine aliquots are placed in a single vessel with similarly computed sub-volumes, the resulting composite may be analyzed to determine the EMCs for constituents of interest. The caveats of the approach include insuring that the index volume is low enough to insure that there is enough sample for the maximum volume aliquot in the composite. In addition, great care must be taken in extracting aliquots for the composite from individual sample bottles in a quantitative manner. This is of paramount importance when substantial amounts of suspended matter are present. In fact, if the analytical protocols for suspended sediment concentration (SSC) are observed, the labor involved may make the method time- and cost-prohibitive.

The compositing approach of choice is usually the V_{Et_V} method illustrated in Figure 5.3. The procedure requires the use of a somewhat more capable flow metering/sampling equipment suite, but initial costs are likely to be far outweighed by savings in staff time and analysis. As may be seen in the schematic, sub-samples of constant volume are withdrawn at equal increments of total stormwater flow volume. These sub-samples are deposited directly into the composite vessel in the field, and at the end of the event, the flow-weighted composite is complete and ready for retrieval and analysis. As may be inferred from Figure 5.3, the total flow volume increment may be reduced to a point so that n is quite large, and the resulting composite represents the entire hydrograph at a very fine scale. An additional advantage of the method is that no post-storm effort is required in the laboratory to make up the composite. The entire composite is constructed in the field, and the measured concentrations in the vessel are representative of the EMCs for constituents of interest.

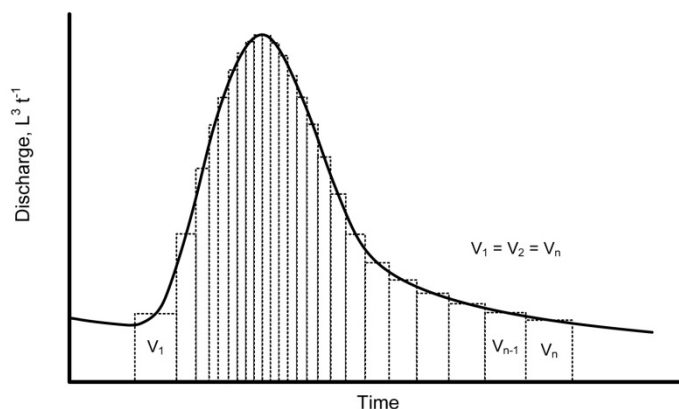


Figure 5.3. Equal volume, variable time, flow-weighted composite
(Graphic courtesy of T. Grizzard)

5.3.2.6 -- Maintenance Monitoring

For a technology seeking a **GUD**, samples shall be collected past one maintenance cycle to verify maintenance requirements and to document how performance changes over time. To accomplish this goal, monitoring is required for the qualifying event just prior to and immediately after maintenance. If it can be shown that maintenance returns the BMP to its original condition (e.g., total replacement of treatment material), there is no need to show performance past one maintenance cycle (however, the requirement of meeting the minimum number of monitored storms must still be met [See **Section 5.3.2.4 -- Minimum Number of Events Required to be Sampled**]). For expected maintenance cycles greater than two years, the proponent must agree to conduct long-term periodic monitoring to show how performance varies over time and must monitor the qualifying events immediately before and after maintenance.

5.3.3 -- Phosphorus Monitoring Overview

This VTAP field monitoring protocol provides guidelines for use by a proponent to obtain a **GUD**, and as applicable, to obtain either a **PUD** or **CUD**. Once granted a **GUD**, the BMP will be assigned a pollutant removal (PR) rating that may be used in the DCR Runoff Reduction Method. For phosphorus removal, the PR rating will be calculated from the direct measurement of total phosphorus (TP) loads into and out of the BMP system. Summed with the total phosphorus load from the bypassed annual discharge volume (untreated), the total phosphorus load reduction for the drainage area may be determined and used to assess compliance with the DCR average annual phosphorus load limit.

Because phosphorus PR ratings are based on demonstrated TP load reductions, a short description of the forms of phosphorus found in stormwater is provided here in order to gain an appreciation of their dynamic nature and relative treatability by different classes of BMPs.

Phosphorus exists in aqueous systems in a variety of forms. For standardization of nomenclature and consistency of measurement, the following classifications are used: total phosphorus (TP), total soluble phosphorus (TSP), soluble reactive phosphorus (SRP), and particulate phosphorus (PP). TP, TSP, and SRP are directly measured in the laboratory, whereas PP is calculated by difference. The sum of all phosphorus components is termed total phosphorus (TP). TSP and PP are differentiated by whether or not they pass through a 0.45- μ m membrane filter.

Phosphorus speciation is site, watershed, land use, water chemistry, and time sensitive. Phosphorus fate will shift speciation as water chemistry (i.e., pH, alkalinity, temperature, redox potential, and concentration) naturally changes in stormwater runoff and treatment systems. These shifts in speciation may occur both during the transport and/or storage of PP within the conveyance and treatment structures, such as piping, detention/retention facilities, settling basins, and filtration/infiltration practices. Speciation shifts may result in PP re-solubilizing into TSP and becoming readily bio-available. Despite having been previously captured in the PP form, phosphorus that has transitioned to a soluble form has a high propensity to be carried downstream into a surface water body to feed algal growth.

The percentage of TP found in the TSP form may vary widely, as reflected in the National Stormwater Quality Database (Pitt 2008), which lists median TP and median TSP concentrations for a variety of land uses. Variations in phosphorus speciation may have a significant impact on BMP performance. BMPs using sedimentation and/or filtration processes can be effective for PP removal. However, unless they incorporate materials that utilize sorption or produce chemical reactions with TSP, they have limited effectiveness for TSP removal. Consequently, BMPs that target PP can potentially demonstrate TP removal at test sites where percent TSP is low, but may have poor TP removals at test sites where percent TSP is relatively high.

Additionally, some naturally-based materials and soil-based materials that have the ability to utilize sorption or produce chemical reactions with TSP may have a tendency to de-sorb or release TSP over time. Some waste materials may be successful with TSP capture but have proven to leach other toxic materials such as heavy metals or organics. These potential negative performance parameters should be quantified upfront.

5.4 -- Monitoring System Design and Installation

The information provided in this section should be considered when designing the monitoring system for the collection of performance and maintenance data.

5.4.1 -- Monitoring System Design

The physical layout of the monitoring system may have direct impacts on BMP removal efficiency. For example, upstream controls may have an important impact on the level of treatment observed. Likewise, if bypass and overflows are not considered, different results may be expected for overall BMP efficiency. Physical management of the system during the study period (e.g., adjustments to the height of an overflow/bypass weir or gate) may also impact the monitoring results. For this reason, all static and state variables of the BMP must be considered when designing the monitoring system.

When selecting flow monitoring stations, consider the following:

- For stations where flow is to be measured in open channels, the flow measurement facilities should be located where there is suitable primary hydraulic control to support the development of reliable rating curves (i.e., stage-discharge relationships). Suitable primary hydraulic controls for most devices will most often include a properly calibrated weir or flume. Selection of the control should be done carefully to avoid introducing bias

into either water quantity or water quality measurements. If other flow measurement technologies are proposed in the study design (e.g., area-velocity meters), provision must similarly be made for adequate demonstration of precision and accuracy.

- Where possible, stations should be located in reaches of a conveyance where flows tend to be relatively stable and uniform for some distance upstream (approximately 6 channel widths or 12 pipe diameters), in order to better approach "uniform" flow conditions. Steep channel slopes, changes in pipe diameter, conduit junctions, and areas of irregular channel shape (e.g., breaks, repairs, roots, debris, etc) should all be avoided.
- Stations should be located a sufficient distance downstream from inflows to the drainage system to favor uniform flow conditions.
- Monitoring sites in locations that may be affected by backwater and tidal action should be avoided because such conditions may adversely impact the reliable measurement of flow.
- Stations established in pipes, culverts, or tunnels should be located to avoid surcharging (pressure flow) over the normal range of precipitation.
- Sampling stations for the BMP should be located as close as possible to the BMP system inlet and outlet in order to avoid potential sources of contamination that bias the study results (and the derived BMP efficiency data).
- Influent sampling stations should be located sufficiently downstream from inflows to the drainage system to better achieve well-mixed conditions across the channel.
- Sampling chambers designed to produce completely-mixed samples are preferable to sampling from pipe inverts.
- If an automated sampler with a peristaltic pump is to be used, and the access point is a manhole, the water surface elevation should not be excessively deep (i.e., it should be less than 6 meters, or 20 feet, below the elevation of the pump in the sampler, and preferably less than 4.5 meters or 15 feet deep). This is necessary to avoid unacceptable intake velocity reductions due to increased pump suction lift.
- Sampler intake locations should consider the expected velocity profile in the type of channel being used, see Figure 5.4 from Chow (1959). Where possible, TSS measurements should be made on multiple flow-weighted cross-sectional samples at various flows and compared to the point intake TSS value to insure that intake location is not creating bias in sample results.

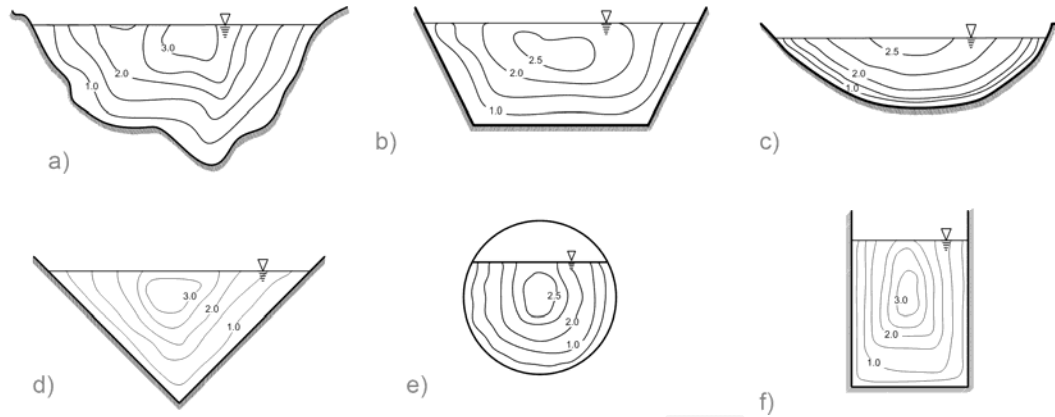


Figure 5.4. Typical velocity distributions (ft./sec.) for a) natural channel, b) trapezoidal channel, c) parabolic channel, d) triangular channel, e) pipe, f) rectangular channel. Modified from Chow (1959) (Graphic courtesy of T. Grizzard)

- In addition, evidence must be provided to insure that carry-over of such compounds between samples (e.g., adherence to the sampling equipment surfaces) is not taking place.
- For systems that bypass runoff, the influent sampling station should be directly upstream of the system and before the flow is split between the treatment system and the bypass. The outflow sampling location should be located directly downstream of the treated flow (i.e., the technology or treatment system outlet) and after the effluent joins the bypass flow. If the treated effluent flow does not join the bypass, the bypass must be monitored after the split.
- It should be noted that sampling points used for National Pollutant Discharge Elimination System (NPDES) permit compliance monitoring may not be appropriate for testing BMPs (e.g., in the situations where there is a contaminant source between the BMP and the outfall of a facility).

The following apply to all monitoring stations:

- Stations should be located where field personnel may safely access the equipment for construction, maintenance, and sample retrieval (i.e., where surface visibility is good and traffic hazards are minimal, and where monitoring personnel are unlikely to be exposed to explosive or toxic atmospheres).
- If automated equipment is to be used, the monitoring system configuration should be such that confined space entry (for equipment installation, routine servicing, and operation) can be performed safely and in compliance with applicable regulations.
- Stations should be located where access and security are good, and vandalism of sampling equipment is unlikely.
- Stations should be located where the channel or storm drain is soundly constructed.
- Groundwater monitoring wells should be established if contamination of groundwater is suspected. Groundwater flow, direction and elevation as well as soil types should be

established before monitoring stations are chosen. Monitoring stations should be located sufficiently down gradient from the BMP in order to intercept infiltrated water from the BMP.

Each candidate sampling station should be visited, preferably during or after a storm to observe the discharge. A wet-weather visit can provide valuable information regarding logistical constraints that may not be readily apparent during dry weather.

5.4.2 -- Minimum Monitoring Equipment Requirements

The following list of equipment is typically the minimum required to conduct field monitoring in conformance with field test protocol:

- **Rainfall Monitoring:** A rainfall monitoring station should be located at, or within ¼-mile of each test site. A tipping bucket rain gauge that measures rainfall volume in no greater than 0.01 inch increments and a maximum intensity measurement capability of no less than 4 in./hr. is required. The rain gauge should interface with a data acquisition system using the same electronic time base as flow measurements and sample event marks.
- **Inlet and Outlet Flow Monitoring:** Flow monitoring equipment should be located at both the BMP inlet and outlet. Both primary and secondary flow measurement devices are required. Primary flow measurement devices include control sections such as weirs and flumes that create a known stage-discharge relationship. Secondary flow measurement devices include floats, ultrasonic transducers, pressure transducers, and bubblers that provide a means for sensing fluid level and either recording it or routing it to an external data acquisition/data logging device. Flow monitoring equipment should have the capability to measure discharge from near zero to full pipe (or cross-section) conditions. The sampling/monitoring sites should be carefully chosen to be consistent with the requirements of the primary devices selected. Generally, this means maintaining a free discharge (no backwater) through the control section. Designing and equipping a system to provide accurate flow measurements under backwater conditions adds unnecessary complexity, and often reduces reliability. Sites should be carefully evaluated for such conditions, and decisions to include them in the evaluation should only be taken after it has been demonstrated that the impacts on the quality of discharge measurements have been satisfactorily addressed.
- **Stage and Bypass Flow Monitoring:** BMPs using filter media should be equipped with sensors that provide data needed to monitor stage-discharge in the test unit. A variety of sensors (e.g., pressure and ultra-sonic) are available to measure water level (i.e., stage). The outlet flow monitor will measure discharge. Deviation from a baseline stage-discharge curve established during hydraulic testing prior to storm event monitoring should be used to assess clogging of the filter media and to determine when maintenance is needed. In addition, water level measurement inside the test unit should be used to determine when internal by-passes occur. The water level sensor should also be interfaced with a data acquisition system to record stage and discharge data under both normal and bypass conditions.
- **Inlet and Outlet Water Sampling:** Grab and composite samples may be collected either manually or by automatic sampler. However, automatic samplers controlled by a flow metering system should be used unless it is demonstrated that alternant methods are

superior or that automatic sampling is infeasible. Automatic samplers should be located at the BMP inlet and outlet, and configured to be activated by the data acquisition/control system in accordance with the sampling scheme (discrete, composite) adopted for the study. Where possible, sampler intakes should be located in sampling chambers designed to provide well-mixed conditions. Otherwise sampler intakes should be mounted in a well-mixed section of the conduit close to the inlet and outlet of the test unit. The sampler intake tubing (and strainer, if any) must be selected to ensure the desired representativeness of the sample. The sampler intake tubing material must be selected to be consistent with the constituents to be analyzed. Sample aliquot collection should be initiated by signals from the data acquisition/control system.

- **In Situ Monitoring:** In situ monitoring equipment such as temperature probes and pH probes should be attached to internal surfaces where well-mixed conditions exist. The probes should also be interfaced with a data acquisition system to record relevant data.
- **Data Acquisition, Recording, and System Control:** The data acquisition system is often included in the same commercial package as the secondary device for flow measurement. Whether integrated or free-standing, the system should not only have multiple channels available to record both analog and digital data, but also have sufficient computing capacity to determine aliquot volumes for the compositing protocol being employed, and to route appropriate activation signals to automatic samplers. The data acquisition system should have a primary power source, a backup power source, and a means of being queried by through an internal cellular or land-line telephone modem.
- **Weatherproof Shelter:** A weatherproof shelter or trailer should be provided to house the data acquisition system and automatic samplers, with adequate clearance for removal of samples and maintenance of equipment. The shelter should also be sized to permit maintenance activities during storm events without exposing equipment to the elements.

All monitoring equipment should be calibrated and maintained in accordance with the recommendations of the equipment providers.

5.5 -- Sample Collection, Analysis, and Quality Control

The following subsections detail the protocol for sample collection, analysis, and quality control. Particular care must be taken to insure that field and laboratory QAPP elements are well-integrated in the overall project plan.

5.5.1 -- Parameter Selection

Analyte selection will be based on the collection of data required to determine BMP performance for total phosphorus reduction and the calculation of PR ratings, or for determining BMP performance relative to achieving regulatory load limits of other pollutants (e.g., for compliance with TMDLs). All samples must be collected and analyzed in a manner that supports the construction of a mass-based assessment of BMP performance. While the analytical work is generally undertaken at a laboratory remote from the sampling site(s), care should be taken that the sampling protocols in use at the site are consistent with the analyses contemplated.

5.5.1.1 -- Required Parameters for Phosphorus Monitoring of Stormwater

Required parameters for phosphorus monitoring of stormwater include, at a minimum:

- TP
- TSP
- SRP (if BMP uses sorption)
- TSS
- SSC
- PSD
- specific gravity.

To better inform the data analysis, SRP data should also be collected. PP may be calculated by subtracting TSP from TP. Suspended sediment data (TSS, SSC and PSD) are required. Other parameters that influence phosphorus speciation, such as pH, alkalinity, temperature, turbidity, and redox potential should also be included in the analytical program, and may be monitored in situ or through sample collection, as appropriate.

To determine percent TSP and TP reduction, the samples must represent the cross-section (be a well-mixed or homogeneous sample) of the sampled water at both the inlet and outlet points of the BMP.

Distribution of particle size has been shown to have an important relationship to PP load in stormwater. Generally, the finer fraction of suspended sediment contains the highest concentration of PP, which suggests that BMPs capable of removing the finer fraction will be more effective at reducing phosphorus load. Therefore, sampling for PSD from SSC samples at the inlet and outlet will provide important information relative to BMP effectiveness for reducing the PP load. Individual analysis of particle size ranges for PP, and the summation of PP load, can be used to corroborate the PP results taken from subtraction of TSP from TP.

Specific gravity provides additional useful information about the ability of a particular BMP to remove PP. In addition, settling velocities of solids are important and may be measured directly or calculated theoretically from specific gravity and PSD data. Settling velocities may give vital information for quantifying BMP sediment removal efficiency (Geosyntec Consultants and Wright Water Engineers, Inc. 2009) and, by extension, PP load reduction.

Due to the potential differences in precision among analytical procedures, the same analytical apparatus and procedures should be employed throughout each test program. Particle-size distributions (PSDs) shall be determined through an appropriate method or combination of methods.

1. Sieve Analysis
2. Coulter Counter
3. Hydrometer
4. Laser Diffraction

A PSD analytical procedure using laser diffraction instrumentation and sieve analysis is attached, **Appendix C – Particle-Size Distribution**.

5.5.1.2 -- Other Parameters

When considering the analytical program, other parameters that support performance evaluation, including those listed in **Appendix B -- List of Parameters for Sampling** should be considered.

5.5.2 -- Accumulated Sediment Sampling

Where appropriate, the sediment accumulation rate in the BMP should be measured to help demonstrate facility performance and to design a maintenance plan. Practical measurement methods would suffice, such as measuring sump sediment depth immediately before sediment cleaning and following test completion. The following constituents shall be analyzed:

- TP
- PSD
- Percent total volatile solids.

Use several grab samples (at least four) collected from various locations within the treatment system to create a composite sample of the sediment. This will ensure that the sample represents the total sediment volume in the treatment system. For QA/QC purposes, collect a field duplicate sample (see following section on field QA/QC). Keep the sediment sample at 4°C during transport and storage prior to analysis. If possible, remove and weigh (or otherwise quantify) the sediment deposited in the system. Quantify or otherwise document gross solids (debris, litter, and other particles exceeding 4,750 microns in diameter). Use volumetric sediment measurements and analyses to help determine maintenance requirements; calculate a solids or TP mass balance; and determine if the sediment quality and quantity are typical for the application.

5.5.3 -- Sample Handling and Custody

Sample handling includes retrieval from the sampling device, packaging, shipment from the site, and storage at the laboratory. Documentation includes sample labels, custody forms, and sample custody logs.

Sample container material, sample preservation, and holding time limits for the analyzed pollutants must be specified in the QAPP. Whether pre-cleaned sample bottles are obtained directly from the analytical laboratory, or bottles are to be obtained from another source, a detailed bottle-cleaning procedure must be included in the QAPP.

Provide preservation during sample collection, as well as during transport. Samples will be preserved in accordance with U.S. EPA-approved methods (U.S. EPA 1983) or *Standard Methods for the Examination of Water and Wastewater* (APHA, AWWA and WEF 2005). Automatic samplers will be cooled to maintain low temperatures throughout the sample collection period.

Samples must be labeled and tracked from collection through delivery to the analytical laboratory in order to insure sample integrity from time of collection to time of receipt in the laboratory. Whenever samples are removed from the flow, or retrieved from an automatic sampler, they must be placed in a cooled transportation case (e.g., a cooler) along with the chain-of-custody record form, pertinent field records, and analysis request forms, and

transported to the laboratory. Temperature in the storage case should be recorded when the samples are introduced and when they are removed at the analytical laboratory. When performing composite sampling, the chain-of-custody form must include a column for entering the time and date of collection of each aliquot so that holding time limits may be determined.

Sample holding times should be assessed with respect to constituents being evaluated, and how long the “tail” of the hydrograph lasts. PSDs and PP/TSP may require holding times as short as 8-12 hours. One way around the short holding time can be collection of multiple composites.

5.5.4 -- Analytical Methods

Proposed analytical methods must be included in the QAPP. Laboratories certified under the Virginia Environmental Laboratory Accreditation Program (VELAP) as provided in 1 VAC 30 Chapter 45 or 1 VAC 30 Chapter 46 must perform the analytical work for applicable constituents.

5.5.4.1 -- Standardized Test Methods

The VELAP certification process requires a review for all methods (protocol, standard operating procedure, and QA/QC) submitted for accreditation. For aquatic systems, such methods are most often based on a limited suite of standardized test methods such as *Methods and Guidance for the Analysis of Water* (U.S. EPA 1999), *Standard Methods for the Examination of Water and Wastewater* (APHA, AWWA and WEF 2005), and the American Society for Testing and Materials D5612-94(2008) (ASTM 2008). Other nationally recognized organizations, such as American Water Works Association (AWWA) and NSF International, have also published methods that may be used if more broadly applied standard methods are not available. Standardized test methods and procedures have the advantage of being prepared by technology specific, expert subcommittees, and the methods typically incorporate a rigorous peer-reviewed data QA/QC.

When preparing samples for shipment to the laboratory, identify:

- Name of the analytical methodology.
- Approved method identifier.
- Sample matrix (aqueous or solid).
- Required method detection limit with appropriate units.
- Sample preservation technique(s) employed.
- Container type.
- Maximum holding time.

5.5.4.2 -- Phosphorus Analysis

TP is largely defined on the basis of how much phosphorus in its various forms will be oxidized into orthophosphate by a strong chemical oxidant (i.e., digested). TSP is measured after filtering the sample with a 0.45-micron membrane filter and digesting the filtrate. SRP is measured on the same filtered sample, but without digestion, and represents the phosphorus directly available to participate in the color-producing reaction. While often taken as a surrogate for orthophosphate, SRP generally includes some additional material that is mobilized by the conditions of the test. The filter excludes most particulates, but some colloidal phosphorus may

be present in the filtrate. The filtrate contains both organic and inorganic forms that are converted to orthophosphate by the digestion process. PP is defined as the sum of all the phosphorus retained on a 0.45- μ m membrane filter during sample filtration and includes particulate and colloidal as well as inorganic and organic phosphorus. Sediment and stray leaf or plant remains that are captured on the filter are generally considered contaminants rather than normally-occurring portions of the TSP form. Different analytical tests used for digestion and analysis of phosphorus may change the amount of phosphorus reported. It is critically important that the laboratory not deviate from specified and approved analytical procedures.

5.5.5 -- Quality Control

One major function of quality control (QC) is to identify, quantify, and reduce both systematic and random error encountered in analytical processes, including variability due to sampling, storage, preparation, analysis, and data manipulations. A properly functioning QC program has the benefit of continuous feedback to the analytical system, and is a mainstay of the continuous quality improvement goal in analytical operations. For more detailed information on laboratory QC, the applicant should consult VELAP at the Virginia Division of Consolidated Laboratory Services (<http://www.dgs.virginia.gov/>). A summary of the types of sample analyses required by a properly functioning laboratory includes field blanks, field duplicate samples, laboratory control samples, method blanks, matrix spike/matrix spike duplicates (MS/MSDs), duplicates, surrogates, laboratory splits (lab duplicates), and reference samples such as performance evaluations or certified reference materials when applicable.

The QC plan should also include:

- QC checks that will be followed for all project activities and the frequency each will occur.
- Control limits for each QC activity and the actions that will take place when these limits are exceeded.
- Applicable statistics that will be used to estimate sample bias and precision.
- Methodology for measurement of accuracy and precision, including the establishment of criteria based on the data quality objectives for the project.
- Methodology for use of blanks, the materials used, the frequency, the criteria for acceptable method blanks and the actions to be taken if criteria are not met.
- Procedure for determining samples to be analyzed in duplicate, the frequency and approximate number.

The QAPP shall provide a table listing all QC sample analyses being performed including the number and type of analyses for each batch of samples. QC activities must constitute no less than 10% of the samples being analyzed, with at least one of each QC procedure specified per sample batch.

5.5.6 -- Monitoring Equipment QA/QC Procedures

The following subsections identify procedures that will help ensure monitoring equipment is operating as intended and that prevent cross-contamination of samples.

5.5.6.1 -- Instrument/Equipment Calibration and Frequency

- **Automated Samplers.** Automated samplers should be calibrated after installation to ensure that the correct volumes of liquid are being retrieved. The condition of the sampler pump and intake tubing, the vertical distance over which the sample must be lifted, and other factors can affect the volume drawn. Therefore, test the sampler after installation and adjust the sampler programming if necessary to be sure the system consistently draws the correct sample volume. Volume delivery takes on an added importance if the sampler is pumping against a variable suction lift.
- **Flow Metering Systems.** Primary devices (e.g., weirs, flume) are often deformed in some way during installation, and small changes in the geometry may have large impacts on the rating relationship. Upon installation, the primary device must be calibrated over its entire measurement range using tracer dilution studies or velocity-area rating studies. Such studies should be repeated periodically during the course of the field study to insure that changes have not taken place.

Secondary devices such as bubblers, floats, or pressure transducers must similarly be calibrated and verified in the field. A stable datum for stage measurements should be established at the time the station is constructed and periodically referred to for subsequent calibrations and verifications. Most devices have well-developed procedures from the applicant, and these should be carefully followed.

- **Rain Gages.** Rain gages should be calibrated at the time of installation and periodically inspected/tested throughout the study to insure that operating characteristics have not changed. Tipping bucket rain gages should be located where they are not subject to the effects of wind eddy currents and turbulence. In general, obstructions (e.g., buildings, trees, etc.), should be no closer to the rain gage barrel than 4 times the height of the obstruction above the lip of the gage, and in no case may an obstruction be closer than twice the height of the obstruction above the lip of the gage. Rain gages must be carefully leveled, and periodically tested to insure that indicated rainfall is consistent with the depth of rain applied to the gage.

5.5.6.2 -- Equipment Decontamination

Sampling equipment (sampler head and suction tubing) must be decontaminated between sampling events as necessary and specified under QA/QC procedures to prevent sample cross-contamination. Replace the suction tubing at least once during the test period and more frequently for highly contaminated runoff.

5.5.6.3 -- Inspection/Acceptance of Supplies and Consumables

The purpose of this element is to identify necessary supplies and how to make sure they are available when needed. Examples of supplies and consumables are reagent water, reference standards for calibrating instruments, and bottles of known cleanliness (such as for trace metal analysis).

- Maintain a list of project supplies and consumables that may directly or indirectly affect the quality of the results.
- Identify individuals responsible for maintaining these supplies.
- Check products against acceptance criteria before using the product.

5.5.7 -- Field QA/QC Procedures

Field QA/QC procedures must be carefully integrated with laboratory QA/QC such that the overall program meets the project data quality objectives. When collecting samples from aquatic systems and transporting them to a remote analytical laboratory, several items normally considered as field quality control must be included:

5.5.7.1 -- Field Blanks

Field blanks are prepared after cleaning the equipment by sampling reagent-grade water with the equipment. Field blanks could include sources of contamination introduced by reagent water, sampling equipment, containers, handling, preservation, and analysis. In general, field blanks should be performed prior to sample collection. Because the field blank is an overall measure of all sources of contamination, it is used to determine if there are any blank problems. If problems are encountered with the field blank, then the other components of the sampling process should be evaluated by preparation of other blanks (e.g., method blanks, source solution blanks, bottle blanks, travel blanks, equipment blanks) in order to identify and eliminate the specific problem (see Geosyntec Consultants and Wright Water Engineers, Inc. [2009] for more information).

Field blanks will be used to verify the adequacy of the decontamination process (i.e., to verify that the equipment is not a source of sample contamination). Collect field blanks at the inlet monitoring station where stormwater is expected to contain the highest contaminant concentrations. At a minimum, collect two separate field blanks during the initial equipment startup and testing and at least one additional blank midway through the sampling program. Collect more frequent blank samples if site conditions warrant (e.g., following an event with unusually high contaminant concentrations). Collect field blanks after decontaminating the equipment and after at least one storm event has been sampled (to “contaminate” the equipment). The field-blank sample should represent a volume of stormwater that will be collected during a typical sampling event.

Analyze field blanks as regular samples with all other appropriate quality control activities performed. The equipment-rinsate blanks should be below the accepted method detection limit for the constituent of interest. If contamination is observed above the practical quantitative limit for the constituent of interest, corrective actions must be taken (e.g., modifying decontamination procedures, replacing suction tubing, etc.).

5.5.7.2 -- Field Duplicate Samples

A field duplicate sample is a second independent sample collected at the same location and with the same equipment. Duplicates are primarily used to assess the variation attributable to sample collection procedure and sample matrix effects. Duplicates for composite sampling may be obtained by splitting a composite sample of adequate volume into two separate samples, using an acceptable sample splitting technique. Duplicates for grab samples should be collected by filling two grab sample bottles at the same location. Field duplicate samples should be collected at a frequency of 5% or a minimum of one per event, whichever is greater. Field duplicate samples are used to provide a measure of the representativeness of the sampling and analysis procedures. Please note that splitting a previously collected composite sample does not assess sample collection procedures.

5.5.7.3 -- Field Sample Volumes

Sufficient sample volumes need to be collected to enable the required laboratory QA/QC analysis to be conducted. A table indicating what sample volumes are needed for regular sampling and for QA/QC sampling must be included in the QAPP.

5.5.7.4 -- Recordkeeping

Field logbooks must be maintained to record any relevant information noted at the collection time or during site visits. Notations about any activities or issues that could affect sample quality must be made (e.g., sample integrity, test site alterations, maintenance activities, and improperly functioning equipment). At a minimum, the field notebook must include the date and time, field staff names, weather conditions, number of samples collected, sample description and label information, field measurements, field QC sample identification, and sampling equipment condition. Records of sediment accumulation measurements are also appropriately entered into the field logbook. In particular, any conditions in the tributary basin that could affect sample quality must be noted (e.g., construction activities, reported spills, other pollutant sources). A field data form can be used in place of, or to supplement, the field logbook. If a field data form will be used, a sample form must be provided in the QAPP.

5.5.7.5 -- Chain of Custody

All sample custody and transfer procedures should be based on procedures outlined in *NPDES Storm Water Sampling Guidance Document* (EPA 833-B-92-001) (U.S. EPA 1992, available at <http://www.epa.gov/npdes/pubs/owm0093.pdf>). These procedures emphasize careful documentation of sample collection, labeling, and transfer, and storage procedures. Pre-formatted chain-of-custody forms should be used to document the transfer of samples to the laboratory and the analysis to be conducted on each bottle. A sample chain of custody form must be provided in the QAPP.

5.5.8 -- Laboratory QA/QC Procedures

In general, while a pilot designation of a BMP can be received based upon laboratory performance, laboratory studies cannot be used for field phosphorus performance claims. Laboratory tests, however, are useful for testing aspects of BMPs under controlled conditions. In many cases, it will be necessary to document some aspects of BMP operational characteristics with laboratory data.

Laboratory work for submission under the BMP certification process must be performed by a VELAP certified environmental laboratory unless the particular constituent or circumstance does not have a VELAP procedure. QA/QC procedures and standard operating procedures must be documented in the laboratory quality manual and also referenced in the project QAPP. Project requirements for laboratory QA/QC systems including, but not limited to, laboratory control samples, method blanks, matrix spike/matrix spike duplicates (MS/MSDs), laboratory duplicates, surrogates, and proficiency test samples or certified reference materials must be documented in the QAPP. Policies of corrective action, management audit, data integrity and ethics are outlined in the laboratory quality manual as well.

5.5.9 -- Data Quality Indicators and Measurement Quality Objectives

The data quality indicators (DQIs) help define the quality and usefulness of the sample data, based on the factors that may impact the overall quality of the data. By defining the limits of the systematic and random errors that can impact data, the quality and usefulness of the data and impacts on decisions can be determined. The measurement quality objectives (MQOs) answer the question of how accurate the measurements need to be in order to get accurate data. For BMP effectiveness monitoring, individual measurement results are combined into data sets for statistical evaluation. The MQOs for accuracy, precision, bias, and required reporting limits must be presented in the QAPP. Reporting limits listed in **Appendix D -- Laboratory Methods** should be met. In some cases, a laboratory may need to reduce laboratory contamination sources to meet the reporting limits.

The following paragraphs define the DQIs and specify the methods used to evaluate them. Further detail on the use of these methods to evaluate the precision, accuracy, and completeness of data is provided in **Section 5.5.7 -- Field QA/QC Procedures** and **Section 5.5.8 -- Laboratory QA/QC Procedures**.

- **Precision** is a measure of the scatter in the data due to random error and is stated in terms of percent relative standard deviation or relative percent difference. The primary sources of random error are the sampling and analytical procedures. The total precision of results can be estimated from the results of field-duplicate samples. For laboratory analysis, precision is assessed using laboratory duplicates.
- **Bias** is a measure of the difference between the result for a parameter and the true value due to systematic errors. Bias is the difference between the mean of an infinite number of replicate results and the true value of the parameter being measured. Potential sources of bias include: (1) sample collection methods, (2) physical or chemical instability of samples, (3) interference effects, (4) inability to measure all forms of a parameter, (5) calibration of the measurement system, and (6) contamination.

Previous studies pertaining to the sources of bias due to sampling have led to the recommended procedures currently in use. Thus, careful adherence to established procedures for collection, preservation, transportation, and storage of samples reduces or eliminates most sources of bias. Bias affecting laboratory measurement procedures are assessed by the use of matrix spike recovery, method blanks, and check samples in accordance with the laboratory QA plan. Analysis of split samples provides an estimate of overall sampling bias including variation in concentration due to sample heterogeneity. Matrix spikes are used to detect interference effects due to the sample matrix. An estimate of bias due to calibration is calculated from the difference between the check standard results and the true concentration.

- **Representativeness** is achieved by selecting sampling locations, sampler intakes, methods, and times so that the data describe the conditions that the project seeks to evaluate. The representativeness of project data is achieved by choosing the sampling sites using criteria specified in this document. Additionally, representativeness of the data is assured through definition of target storms and qualifying conditions, and through programming of the automated samplers to collect aliquots at appropriate intervals during the storm events.

- **Comparability** refers to the ability to compare the data from the project to other data sources. Data comparability is assured by selection of standardized procedures, adherence to this protocol, and by clearly stating any non-standard requirements.
- **Completeness** refers to the amount of useable data obtained during the project. Data completeness can be determined primarily by the success of flow data, rainfall data, and water quality sample collection during storm events.

5.6 -- Data Verification, Validation, and Certification

Guidance concerning the data verification and validation processes are presented in the following subsections. A detailed guidance of the data verification and validation process is available from EPA at: http://www.epa.gov/quality/qa_docs.html (*Guidance on Environmental Data Verification and Data Validation* (EPA QA/G-8) (EPA 2002a)).

5.6.1 -- Data Verification and Certification

Data verification is the process after QA/QC in which the project's data records are reviewed for completeness, for actual content, and against project specifications. The goal of data verification is to ensure and document that the reported results reflect the work that was actually performed. Data verification applies to activities in the field as well as in the laboratory and is conducted during or at the culmination of data collection activities. Data verification includes checking the transference of data generated in the field via hard copies to digital datasets.

The project manager, field collectors, and/or lab personnel need to coordinate efforts to produce verified data and data verification records. These documents should be submitted to the technical advisor for data validation.

Verified data have been carefully reviewed. Any changes in the data from that originally reported should be accompanied by an initialed/signed note of explanation from the field data collector, the laboratory, or the data verifier. The data verification records summarize the technical non-compliance issues or shortcomings of the data produced. Deficient data should be identified, and any corrective actions should be documented. When data are not available to perform verification, the data verification records should state that the data could not be verified. The data verification records should include checklists, handwritten notes, and data tables (electronic and/or hard copies). Definitions and supporting documentation for any laboratory qualifiers assigned should be documented. The data verification records also include a signed and dated certification statement from the verifier and project manager: "I, [verifier/project manager] acknowledge that the data associated with this project have been verified."

5.6.2 -- Data Validation and Certification

Data validation is used to determine the quality of a specific data set relative to the end use. Data validation criteria are based upon the measurement quality objectives (MQOs) developed in the QAPP. The goal of data validation is to evaluate whether the data quality goals established during the planning phase have been achieved. Data validation includes a determination, where possible, of the reasons for any failure to meet method, procedural, and an evaluation of the impact of such failure on the overall data set.

Data validation is based on the verified data and data verification records. Validated data should be the same as the verified data with the addition of any data validation qualifiers that were assigned by the data validator. Any corrections or changes noted during the data validator's review of the verified data should be reflected in the validated data. Data that change as the result of validation must be reverified.

The basic steps to validation are listed below:

1. Check that all requested analyses were performed and reported. Check that all requested QA/QC samples were analyzed and reported.
2. Check sample holding times to ensure that all samples were extracted and analyzed within the allowed sample holding times.
3. Check that the laboratory's performance objectives for accuracy and precision were achieved. This includes a check of method blanks, detection limits, laboratory duplicates, matrix spikes and matrix spike duplicates, laboratory control samples, and standard reference materials.
4. Check that field QA/QC was acceptable. This includes a check of equipment blanks, field duplicates, and chain-of-custody procedures.
5. Check that surrogate recoveries were within laboratory control limits.
6. Assign data qualifiers as needed to alert potential users of any uncertainties that should be considered during data interpretation.

If the field performance objectives were achieved, further data validation is not generally needed. Specifics of the instrument calibration, mass spectral information, and run logs are not usually recommended for review unless there is a suspected problem or the data are deemed critical. If performance objectives were not achieved (e.g., due to contaminated blanks, matrix interference, or other specific problems in laboratory performance), the resulting data should be qualified.

The data validation process should result in the following three outcomes: 1) validated data, 2) a data validation report, and 3) a certification statement. A data validation report is the primary means of communication between the data validator and the data user. The report should provide sufficient detail for the data user to have an overall idea of the quality of the data and how well the project needs were met. The report should be written in easy to read "lay language," as much as is feasible, since it is likely to be read by decision makers that may not have the same level of technical understanding that is typically shared by the researchers and technical advisors. The report should include the following items:

- objectives for sampling and analysis;
- summary of the project record needs as assessed from the QAPP;
- field and laboratory data documentation (e.g., laboratory certification sheets, chain of custody forms);
- deficiencies encountered and the impact of deficiencies on the overall data quality;
- data validation qualifier definitions, assignments, and reasons for the assignments (also include these in the validated data set), and;
- updates and/or corrections to the verified data with explanations for the change.

The validator should sign and date a certification statement acknowledging that the data have been validated. "I, [data validator], acknowledge that the data associated with this project have been validated." In addition, DCR and/or its evaluators may ask the validator for clarifications and additional information at any time during the evaluation process.

5.7 -- Data Management

This element gives an overview for managing data generated throughout the project. Data management is an important component of field monitoring. You need to be able to store, retrieve, and transfer the diverse hard copy and electronic information generated by your monitoring program. Before beginning monitoring, establish the following data repositories:

- central file to accommodate and archive hard copy information expected to be generated and practical dating and filing procedures to help ensure that superseded information is not confused with current information, and;
- database to accommodate digital information such as results of laboratory analyses, information recorded by data loggers (e.g., flow, precipitation, in-situ water quality measurements), maps in CAD or GIS, spreadsheets, etc.

After data from the field have been received, store the originals in the project file. Data reports should be reviewed for completeness as soon as they are received from the laboratory. Reports should be checked to ensure all requested analyses were performed and all required QA data are reported for each sample batch. If problems with reporting or laboratory performance are encountered, corrective actions (re-submittal of data sheets or sample re-analysis) should be performed prior to final data reporting or data analysis.

5.8 -- Data Quality Assessment

Data quality assessment (DQA) is the scientific and statistical evaluation of environmental data to determine if they meet the planning objectives of the project, and thus are of the right type, quality, and quantity to support their intended use. EPA's *Data Quality Assessment: A Reviewer's Guide* (EPA QA/G-9R) (U.S. EPA 2006a) is a non-technical guidance that describes broadly the statistical aspects of DQA in evaluating environmental data sets. A more detailed discussion about DQA graphical and statistical tools may be found in the companion guidance document, *Data Quality Assessment: Statistical Methods for Practitioners* (EPA QA/G-9S) (U.S. EPA 2006b). Both documents are available at http://www.epa.gov/quality/qa_docs.html. In general, DQA should follow the following steps:

- State well-defined project objectives and criteria.
- Provide the statistical hypotheses, including a null hypothesis as well as an alternative hypothesis. Alternatively, provide confidence intervals or tolerance intervals (e.g., 'We are 95% confident that at least 80% of the population is above the threshold value.').
- Describe the tolerance for uncertainty. For example, list the Type I error (false positive) and Type II error (false negative).
- Calculate basic descriptive statistics of the data and generate graphs of the data.
- Document the test statistical method used and the critical value or *p*-value.
- List the assumptions underlying the statistical method.
- Document the method used to verify each assumption together with the results from the investigations.
- Describe any corrective actions that were taken.
- Report the statistical results at the specified significance level.

An acceptable means of using direct measurements, modeling, and statistical analysis will be used to assess performance. For an in-depth discussion of appropriate statistical analysis procedures, including hypothesis driven techniques, refer to *Urban Stormwater BMP*

Performance Monitoring (Geosyntec Consultants and Wright Water Engineers, Inc. [2009] for EPA and the American Society of Civil Engineers). In addition to the statistical characterization, it is desirable to advance further understanding of the physiochemical treatment processes used by the device, and be able to assess and predict how mass moves through the device during each event. Both statistical and mechanistic approaches are necessary to fully characterize performance and reliability of the device.

5.9 -- Pollutant Removal and Efficiency Rating Methods

The following three types of data are particularly valuable for determining the performance of BMPs in removing water quality pollutants: 1) event mean concentrations (EMC); 2) summation of loads (SOL); and 3) Effluent Probability.

- **Event Mean Concentrations** -- The EMC is defined as the total constituent mass divided by the total runoff volume. It is used to represent the flow-proportional average concentration of a parameter during a storm event.
- **Summation of Loads** -- The SOL is determined from concentration and flow data. Loads are particularly important for meeting Virginia's stormwater management regulations and for meeting TMDL implementation plans. Annual loads of pollutants removed by the BMP and cited in the performance claim should be calculated, however, these values are only as accurate as the percent of storm flow captured by the device.
- **Effluent Probability** -- The effluent probability method provides a statistical view of the influent and effluent water quality. With this method, the data analyzer determines if the influent and effluent mean EMCs or loads are statistically different from one another and develops either a cumulative distribution function of influent and effluent quality or a standard parallel probability plot. The ranked phosphorus EMC (log scale) can be plotted as a function of the probability. Improvements in water quality will be apparent from the differences in the input and output data. The ability of the MTD to meet a desired performance goal can be determined from this plot, as shown in Figure 5.5, which is an example for suspended sediment reported by Geosyntec Consultants and Wright Water Engineers, Inc. (2009).

The cumulative pollutant mass in and out should be calculated using all qualifying events. The mass is calculated as the product of the EMC and the total volume for each event. The annual mass in and out is found by taking the measured cumulative mass values and multiplying them by the ratio of the expected annual rainfall depth, divided by the cumulative rainfall depth from the qualifying events.

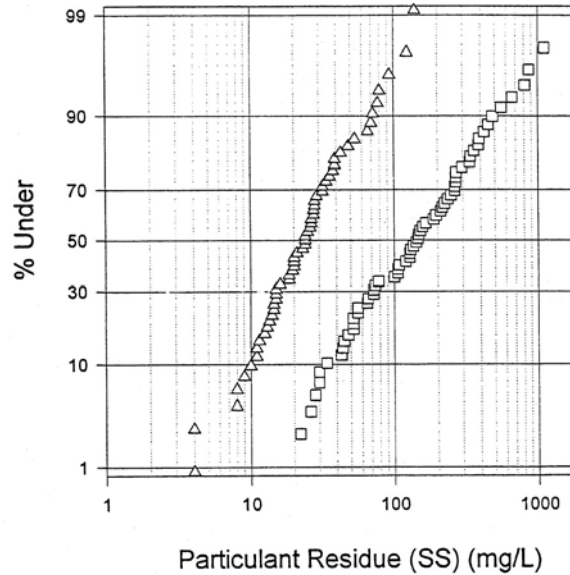


Figure 5.5. Illustration of effluent probability method for assessing efficiency of stormwater treatment devices

Example Pollutant Removal Efficiency Calculation

The following equation is used to calculate load reduction efficiencies for TP:

$$\% \text{ Total Phosphorus (TP) Load Reduction} = 100 \times (1 - [C/D])$$

where:

C = Sum of Outlet TP Load = (Outlet TP EMC₁)(Flow Volume₁) + (Outlet TP EMC₂)(Flow Volume₂) + (Outlet TP EMC_n)(Flow Volume_n)

D = Sum of Inlet TP Load = (Inlet TP EMC₁)(Flow Volume₁) + (Inlet TP EMC₂)(Flow Volume₂) + (Inlet TP EMC_n)(Flow Volume_n)

EMC = event mean concentration (concentration of a flow-weighted composite sample)

n = number of qualified sampling events

SOL calculations are based on pollutant concentrations and flow volume. Each storm event will be characterized with respect to flow and pollutant concentrations (i.e., EMC) at the inlet and outlet of the test unit. The loads from each storm event are summed to provide an overall load reduction efficiency over the course of the monitoring program. Consistent with load limits for TP in the proposed Virginia stormwater regulations, and the load limits established for TMDL waters, the SOL approach calculates removal efficiencies based on data collected from a year, or more, of monitoring.

6 -- Application and Reporting

For efficient review of the application for a **Pilot Use Designation (PUD)**, **Conditional Use Designation (CUD)**, or **General Use Designation (GUD)**, complete all required components before submitting the application to DCR. In addition to providing the information requested in this document, DCR, the Clearinghouse Committee, and/or other evaluators contracted by DCR may request additional information on a case-by-case basis.

At a minimum, an application *must* include:

- Use Designation Application Form
- Performance Claim
- Theory/Technology Description
- Technical Evaluation Report
- Certification Statement

Submit an electronic version, as a CD or E-mail attachment, to DCR:

Virginia Department of Conservation and Recreation
Division of Soil and Water Conservation
Stormwater Management BMP Clearinghouse
203 Governor Street, Suite 206
Richmond, VA 23219-2094

E-mail: SWMESquestions@dcr.virginia.gov

For assistance, please contact DCR's Virginia Stormwater Management Program.

E-mail: SWMESquestions@dcr.virginia.gov

6.1 -- Use Designation Application Form

Complete the use designation application form, **Appendix E -- Use Designation Application Form**.

- Develop a title for the technology assessment project and use this title in all submittals associated with the project (e.g., QAPP, Status Reports, Technical Evaluation Report).
- Be sure to check the desired designation level for which the technology is to be evaluated: **Pilot Use Designation**, **Conditional Use Designation**, or **General Use Designation** (See **Section 3 -- BMP Certification Designations**).
- If either the **PUD** or the **CUD** has been certified previously by Virginia DCR or certification has been granted in another state, indicate that this designation has been achieved, and include the date of certification.

6.2 -- Performance Claim

The performance claim will be used to evaluate the use designation. Performance claims should be objective, quantifiable, replicable, and defensible. Wherever possible, include information

about anticipated performance in relation to climate, design storm and/or site conditions. Claims that are overstated should be avoided, as they may not be achievable.

Because the Virginia Stormwater Management Program (VSMP) regulations focus water quality compliance criteria on reduction of total phosphorus (TP), water quality certification in Virginia is awarded only for TP removal at this time (refer to **Section 2.3 -- Stormwater Runoff Quality Control**). Thus proponents of BMPs seeking certification for runoff quality control in Virginia must include total phosphorus reduction claims.

The performance claim should include the following descriptions:

- List of pollutant constituents that will be used to evaluate performance.
- Reduction of TP and other pollutants from stormwater runoff and what those reductions are based upon (i.e., reduction of the event mean concentration [EMC] through the BMP's treatment processes, reduction of runoff volume, a combination of both, etc.). See **Appendix F -- Treatment Efficiency Calculation Methods**.
- The conditions under which those reductions were achieved; e.g., the specific influent and effluent concentrations of pollutants in tests (mean/median/range), the particle-size distribution of sediments in tests (specify D_{50}), the flow volumes treated versus volumes that by-passed the BMP, etc.
- Application limitations of technology if known to exist.
- The basis for sizing of the technology (e.g., hydraulic loading at a specific head, concentration of influent, etc.).

6.3 -- Theory/Technology Description

Begin this section by listing the title of the practice and include a photograph of the BMP. Then provide a detailed description of the stormwater BMP. The description should ensure that the reader can understand completely how the technology works.

This section is to be organized in such a way that the information can be lifted from the application and included on the Clearinghouse. Thus, the application should contain as many of the elements from the list below as applicable. At a minimum, all topic headings should be addressed. The standard and specifications information for non-proprietary, post-construction BMPs listed on the Clearinghouse can be used as examples for the types of information to provide and the format to use in presenting the information (www.vwrrc.vt.edu/swc).

6.3.1 -- Description of Practice

Provide a detailed description of how the stormwater BMP works and include the purpose of the BMP:

- Summarize the underlying scientific and engineering principles for the technology. Describe the physical, chemical, or biological treatment processes.
- Describe significant modifications and technical advancements in the technology design.
- Include details on the relevant treatment mechanisms such as those in Table 6.1.

Table 6.1. Measurements for various BMP mechanisms

Mechanism	Measurement
Exchange Capacity / Sorption Capacity (dissolved pollutants)	Each medium or soil's anion or cation exchange capacity and target pollutant's overall removal capacity indicated by isotherms (mass/mass) and breakthrough (pollutant load per volume) analyses (capturing typical range of stormwater pollutant concentrations and hydraulic loading rates).
Sorption	Capacity -- Pollutant mass absorbed or adsorbed per mass (mass/mass). Absorbent type -- Each medium's percent organic matter or organic carbon.
Gravity Separation	Detention time, length to width ratio, hydraulic loading rate for design flow, removal efficiency versus flow rate, particle-size distribution, and specific gravity for each system type or size.
Filtration	Filter media grain size distribution, clean media hydraulic conductivity, hydraulic conductivity versus sediment loading (provide sediment grain size distribution and dry density used in analysis), provide typical and maximum operational hydraulic gradient.
Biological	Describe target pollutant's specific degradation mechanisms and estimated half-life versus temperature, provide estimated stormwater contact time (or detention time) for design flow, and provide target pollutant's estimated treatment efficiency versus flow rate.

6.3.2 -- Performance Criteria

List the expected treatment performance capabilities. Describe the advantages of the technology compared to conventional stormwater systems providing comparable stormwater control.

6.3.3 -- Site Installation Requirements and Impacts

Address any and all site installation requirements and likely impacts resulting from the installation of the technology. As a guide, be sure to consider at least the following:

- **Siting location** – Contributing drainage area, upstream controls (non-structural and structural), available space needed, soil characteristics, hydraulic grade requirements, hydraulic capacity, depth to water table, pretreatment requirements, etc.
- **Land use** – Provide the applications that the manufacturer recommends for the technology (e.g., land uses such as roadways, high-use sites, commercial, industrial, residential runoff areas). Give the rationale for the recommendations. List restrictions to installations within proximity of underground utilities, overhead wires, and hotspot land uses. Provide needed setbacks from buildings and vehicle loading allowances. Report any utility requirements.
- **Limitations** – Consider the physical constraints to installing the BMP within karst terrain; steep terrain; flat terrain; tidal areas; sites with shallow groundwater tables; cold

climates; types of soil; linear highway sites; proximity to wells, septic systems and buildings, etc. Also include limitations associated with the BMP's weight and buoyancy, transportability, durability, energy requirements, consumable materials, etc. Describe whether the following safety considerations favor or limit the technology's use: facility depth limits for access and safety and hazardous materials spill risk. Describe how the limitation factors affect the technology.

- **Environmental impacts** – Describe likely impacts resulting from the construction, operation, and maintenance of the technology. Address community and environmental concerns, including safety risks and liability issues, local codes, winter operation, mosquitoes, aesthetics, etc.

6.3.4 -- Design and Sizing

Divide this section into specific subsections that adequately describe design and sizing. The use of tables can be helpful to convey information. Table format should follow that in the standard and specifications information for non-proprietary, post-construction BMPs listed on the Clearinghouse (www.vwrrc.vt.edu/swc).

Show standard drawings, including a schematic of the technology and a process flow diagram. Photographs may also be useful. Describe any alternative technology configurations.

Describe the following information.

- Siting and design specifications to achieve stated performance, include:
 - Pollutants that should and could be addressed;
 - Pollutants that will not be addressed;
 - Pollutants that may be increased;
 - Stormwater constituent limitations (pollutants and other constituents), including fouling factors;
 - Range of operating conditions for the technology, including minimal, maximal, and optimal influent conditions to achieve the performance goals and standards, and for reliability of the technology;
 - Pollutant removal at water quality design treatment flow or water treatment volume and for representative stormwater characteristics;
 - Design residence time, vertical/horizontal velocities, surface overflow rate, and other parameters relevant to the process;
 - Description of bypass process; and
 - Description of pretreatment and preconditioning of stormwater, if appropriate to achieve stated performance of the BMP.
- Physical description of each treatment system component, including the following if applicable:
 - Engineering plans/diagrams showing each of the functional components;
 - Equipment dimensions;
 - Description of each component's capacity; and
 - Media or soil head-loss curves.

Provide a detailed description of the overall sizing methodology. Include a discussion of technology hydraulics (design flow, by-pass flow, hydraulic grade line, scour velocities, etc.) and system sizing to meet performance standards and goals (e.g., to handle the water quality

volume, rate of runoff, type of storm, or recharge requirements). When applicable, include the structural design, hydraulic design, soil infiltration rate testing, specific media flow rate (design velocity), etc.

6.3.5 -- Material Specifications

When applicable, include a table that lists each construction material. For non-proprietary and patented materials, include specifications. Include raw material specifications for all non-proprietary treatment media.

6.3.6 -- Construction Sequence and Inspection

List the steps to construction in chronological order. Begin with protection during site construction.

Describe the following:

- The role the proponent takes in design and construction.
- Technology availability (e.g., where do the major components come from and how much lead time is needed).
- Include estimate of typical installation time.
- Provisions for factors such as structural integrity, water tightness, and buoyancy.
- Types of problems that can occur/have occurred in designing and installing the technology.
- Methods for diagnosing and correcting potential problems; identify who is responsible to diagnose and correct problems.
- Impacts to the technology's effectiveness if problems are not corrected.

6.3.7 -- Operation and Maintenance

Describe special operation instructions and maintenance needed to sustain performance, include:

- Whether the technology can be damaged due to delayed maintenance, and if so, tell how it is restored.
- How inspections are performed and their frequency. Recommended maintenance schedule and basis for this estimated maintenance frequency. Preventative maintenance procedures implemented during the course of the field test as well as long-term maintenance needs.
- How operations and maintenance are performed. Personnel and equipment needs to operate and maintain the BMP. Maintenance checklist. Availability of supplies, replacement materials and/or parts (e.g., filter media).
- Maintenance area accessibility by people and equipment; describe access ports, including dimensions. List special equipment or methods needed for access and identify any confined space entry areas.
- Generation, handling, removal, and disposal of discharges, emissions, and waste byproducts in terms of mass balance, maintenance requirements, and cost.
- Projected operational and maintenance (O&M) costs. Maintenance service contract availability. Include information about items that affect O&M costs: equipment rental, mobilization and mileage, solids/spent media disposal, etc.

- The number of years the manufacturer has been in business. If applicant goes out of business or product model changes, describe how and where the facility owner will find needed parts, materials, and service.

6.3.8 -- System Longevity

Assuming the BMP is designed, installed, and maintained correctly, what is the expected life of the BMP?

List factors that may cause the BMP to not perform as designed by addressing the following questions:

- Is the technology sensitive to heavy or fine sediment loadings, and is pretreatment required?
- Under what circumstances is the technology likely to add, transform, or release accumulated pollutants?
- If applicable, how long will a soil-based or filter medium last if designed to capture dissolved pollutants?
- If applicable, does the filter medium decompose or is it subject to slime/bacteria growth?
- How is underperformance diagnosed and treated?

In addition answer the following questions:

- What is the warranty?
- What initial/ongoing user support is provided?
- Does the vendor charge for support?

6.3.9 -- References

List any sources of published information, including Websites, cited in the theory/technology description section. List sources alphabetically. Follow the format style used for references included within the standard and specifications information for non-proprietary, post-construction BMPs listed on the Clearinghouse (www.vwrrc.vt.edu/swc).

6.3.10 -- Appendices

Include any additional information requested by the evaluators in appendices.

6.4 -- Technical Evaluation Report (TER)

The Technical Evaluation Report (TER) is to be submitted to DCR as part of the application for technologies seeking a **PUD**, **CUD**, or **GUD** certification. The TER is to be submitted once performance testing is complete and the resulting data have been verified and analyzed.

Modifications to the TER as outlined in this section are allowed, particularly for BMPs seeking **PUD** or **CUD** certification. Only applicable information should be submitted, but if the requested information does not apply to the BMP being assessed, it should be so stated within the TER.

Before submitting a TER for the General Use Designation, the proponent needs to be sure that:

- (1) Field data were obtained that represent urban stormwater conditions expected in Virginia, and;
- (2) The performance testing data meets the requirements in the approved QAPP (See **Section 5.2 -- QAPP and Documentation**).

The DCR will grant a **GUD** based on treatment performance testing and other factors.

6.4.1 TER -- Title Page

- Include: "Virginia Stormwater BMP Technology Evaluation Report."
- List the title of the project. Give the same title as that used on the use designation application.
- List the name of the manufacturer if appropriate.
- Provide the month and year of report submittal.

6.4.2 TER -- Executive Summary

The executive summary should include the following items:

- Technology name, function (e.g., control hydrodynamics, TSS, TP, etc.), and category (e.g., hydrodynamic separator, filter, etc.).
- Desired designation level for which the practice/product is to be evaluated – (1) **Pilot Use Designation**, (2) **Conditional Use Designation**, or (3) **General Use Designation**.
- If either the **Pilot Use Designation** or the **Conditional Use Designation** has been certified previously by DCR, the applicant shall indicate that this designation has been achieved, along with the date of approval.
- If certification has been previously issued by another state, include the certification level, state issuing the certification, and date of certification.
- Based on field monitoring, a performance claim that identifies the technology's intended use and predicts the technology's capabilities to remove contaminants and/or control the quantity of stormwater runoff.
- A summary of the test results and conclusions.
- If basing the application upon testing performed in another state, indicate which, if any, criteria in the VTAP have not been addressed and provide an opinion of how relevant such omission(s) may be to consideration of a Virginia certification.

6.4.3 TER -- Introduction

The introduction section of the TER should provide the following information:

- Performance claim.
- Technology description: Summarize how the BMP operates, the specific applicability of the BMP, range of runoff control and/or contaminant removal characteristics, range of site installation characteristics (include a sizing chart if appropriate), limitations of the BMP, operation and maintenance requirements (include safety issues and handling of collected materials).
- Project description: Describe where testing occurred, over what time period, and the number of storms monitored.
- Key contacts: Include the name and contact information, including E-mail addresses of key contacts, where questions and correspondences should be addressed.

- Other pertinent information of use to the evaluators.

6.4.4 TER -- Test Methods and Procedures Used

This section should include descriptions of how data were obtained.

If laboratory tests were performed for **PUD** certification, or included for supplemental information for a **CUD** or **GUD** certification, the author should include:

- Detailed test facility descriptions (photos, illustrations, process/flow diagrams).
- Treatment and hydraulic design flow.
- Loading rates on a unit basis.
- Dead storage/detention volumes.
- Media type/quantity/thickness.

If a less than full-scale setup (e.g., single cartridge testing) is tested in the laboratory and included for supplemental information, the author should describe the ratios to the full-scale device (sump capacity, flow paths, material differences, etc.).

For all BMPs seeking certification (at either the PUD, CUD, or GUD level), whether the testing occurred in the laboratory or in the field, include the requested information:

- Influent and effluent PSD, TSS and SSC requirements.
- Representative PSDs and gravimetric TSS and SSC measurements to distribute the PSD % volume data for each sample of the influent and effluent.
- Representative method of sampling and sampling volume to generate a representative PSD; and suspended, settleable and sediment gravimetric fractions.
- Representative gravimetric measurement of the suspended fraction (1 to ~ 25 μm), settleable fraction (~ 25 to 75 μm) and sediment fraction (> 75 μm) for influent and effluent.
- Representative hydrologic, chemical and particulate matter loading rates.
- Representative quality assurance and quality control of the testing methods and analytical methods; for example, what does a mass balance result indicate.

For adsorptive-filtration media and soil-based treatment practices, the following information is mandatory at all certification levels (**PUD**, **CUD**, and **GUD**). Proprietary information not to be made public should be identified in the report for DCR to address its confidentiality.

1. Granulometric media properties:
 - a. Representative media size gradation, i.e., media size distribution and statistical indices;
 - b. Representative media specific gravity;
 - c. Representative media specific surface area (not surface area of system, i.e., cartridge).
2. Representative mechanisms; i.e., filtration mechanisms that range from straining to physical-chemical phenomena.
3. Geometric and hydrodynamic properties of system including surface loading rates, contact time, and head-loss models. In this case surface area is geometric surface area of the deployment system for the media, i.e., the area orthogonal to flow paths, as in Darcy's Law.
4. Chemical applications, such as coagulants and flocculants upstream of the filter, if used.
5. Backwash criteria based on hydraulics and backwash frequency, if using backwash.

6. Media stratification and inter-mixing.
7. Standardized isotherm, kinetics and breakthrough parameters.
8. Standardized desorption testing.

If field tests were performed, the author of the TER should characterize field sites by including the following information:

- Detailed site information including a site map. This information should include land cover type, land use activities location, site conditions, site elevations and slopes, location of sampling equipment, location of on-site stormwater collection system, a description of any upstream BMPs, and the name of downstream receiving waters.
- Description of special circumstances (e.g., pretreatment, bypass conditions, retention/detention facilities).
- The method used for sizing the technology for the specific location.

For laboratory and field tests, the author of the TER shall also provide the following information:

- Specifics of the technology used (model number if applicable, size).
- All procedures for obtaining data as described in the approved QAPP, including a description of any deviations from this procedure.
- Include information on QA/QC procedures consistent with those endorsed by the U.S. EPA (See EPA's *Guidance for Quality Assurance Project Plans* [EPA QA/G-5] [2002b], available at http://www.epa.gov/quality/ga_docs.html).
- Inspection protocols used to determine when maintenance was needed.
- Summary of the maintenance procedures implemented during the course of the performance testing as well as necessary long-term maintenance needed to sustain performance (impacts of maintenance activities or lack thereof on performance should be fully quantified).
- The method used to calculate performance.

6.4.5 TER -- Test Equipment Used

List the equipment used to obtain data. If the equipment is standard monitoring equipment, giving the manufacturer's name and model number is appropriate.

6.4.6 TER -- Data Verification and Validation

Include the data validation report and certification statement.

6.4.7 TER -- Data Summary

Provide summaries of laboratory testing and field testing as described in the following subsections.

6.4.7.1 -- Laboratory Testing

Laboratory testing can be used to obtain a **PUD** so should be included in the TER at the conclusion of performance testing. Laboratory testing can only be used to supplement field testing for BMPs seeking the **GUD** or **CUD**.

Summarize the data obtained from laboratory testing in tables and graphs. Be sure to document data that are needed to prove the effectiveness of the practice in relation to the performance claim.

- Develop a table to summarize the characteristics of the BMP including specifics related to sizing. Characteristics may include the model number, size, treatment capacity, storage capacity, etc.
- When a synthetic sediment product, such as Sil-Co-Sil 106, NJDEP particle-size distribution (NJDEP 2009), is used to test the performance of the BMP, include information about the particle-size distribution of the test material (entire distribution, specify D_{50}).
- Summarize the specific settings of each test run, e.g., flow rate, run times, and loading rates.
- Include data to show removal efficiencies of analytes included in the performance claim. If the BMP performance was tested under different conditions (e.g., different flow rates, filter material, etc.), be sure to show data results for each tested condition.
- If solids removal is part of the performance claim, determine the percent capture of the various sized particles under the performance claim conditions (e.g., flow rate).
- For BMPs considered for in-line (internal-bypass) use, determine the sediment effluent retention values and the various sized particles retained during higher flow conditions under the performance claim conditions (e.g., 200% the claimed flow rate).

6.4.7.2 -- Field Testing

Using the validated data, complete the form in **Appendix G -- Stormwater BMP Demonstration Site Summary** for each field test site. The TER author should include additional data of value to understanding the performance results and/or quality control measures.

Maintenance data are required and should include any summary data available about maintenance. The DCR suggests the use of a graphical representation of pollutant removal over time highlighting the times when and how maintenance was performed to verify maintenance cycles.

In the appendices of the TER include individual storm reports. These reports compare data and provide a detailed description of each storm event monitored in an easy-to-read format. Individual storm reports should include:

- **General information** -- storm name, site location, system description, event date, date of last maintenance, antecedent conditions
- **Hydrological information** -- total precipitation (in.); influent peak flow rate (ft.³/sec.); effluent peak flow rate (ft.³/sec.); bypass peak flow rate (ft.³/sec.) if applicable; total influent runoff volume (ft.³); total effluent runoff volume (ft.³); total bypass runoff volume (ft.³) if applicable. Include an event hydrograph with axes of time, flow, and precipitation: time on x-axis (date, time), flow on left-side y-axis (ft.³/sec.); and precipitation on right-side y-axis (in./time). The event hydrograph should include a graph of precipitation, influent flow, effluent flow, and 75% of the design flow.
- **Pollutant information** -- number of influent aliquots, number of effluent aliquots, parameters monitored, influent mean concentrations, effluent mean concentrations, removal efficiency (calculated per **Appendix F -- Treatment Efficiency Calculation Methods**), and reported detection limits.

Additional data may be provided in the TER appendices as well.

6.4.8 TER -- Data Quality Assessment

Submit statistical analyses (e.g., paired t-tests, Wilcoxon signed rank tests, sign tests, or effluent probability method) that were performed on the collected data to determine if pollutant concentrations and loadings are significantly lower in effluent samples relative to influent samples. Also submit additional analyses that may have been performed to examine how the BMP performance varies with factors such as antecedent dry period, storm magnitude, and/or storm intensity.

6.4.9 TER -- Conclusions, Recommendations, and Limitations

All BMPs being assessed, either for a **PUD**, **CUD**, or **GUD**, must include the conclusions, recommendations, and limitations section in the TER. This section shall include the following information:

- All conclusions related to performance testing.
- Expected BMP performance for the range of land uses characteristic of Virginia.
- Recommendations concerning how best to site the BMP relative to factors such as hydraulic grade and space constraints.
- Recommendations pertaining to the operation and maintenance (O&M) procedures of the technology.
- Frequency with which maintenance is needed.
- Special disposal requirements.
- Site limitations that would preclude the use of the technology.
- Limitations on the use or installation of the technology, including information about anticipated performance in relation to climate, design storm, and/or site conditions. List any pretreatment requirements.

If the sampling design is to be used again, either in a later phase of the current study or in a similar study, the technical advisor should evaluate the overall performance of the design. He or she should perform a statistical power analysis that describes the estimated power of the statistical test over the range of possible parameter values. Additional information on power curves (performance curves) is contained in EPA's *Guidance on Systematic Planning using the Data Quality Objectives Process* (EPA QA/G-4) (U.S. EPA 2006c) available at http://www.epa.gov/quality/ga_docs.html.

6.5 -- Certification

In the use designation application, include both the signature of a company representative and date of certification. Use the following certification statement:

"I certify that all information submitted is true and correct. The information was accumulated using approved methods specified in the *Virginia Technology Assessment Protocol*, unless otherwise noted. I understand that any misrepresentation or misuse of information will result in immediate denial of the technology being demonstrated and may prohibit me or the company I represent from seeking future approvals."

6.6 -- Status Reports

During the testing phase, the proponent will need to submit quarterly status reports to DCR. Upon receiving a **PUD** or **CUD** and selecting a testing site, the proponent will need to develop a list of milestones and targeted dates of completion. The milestones should be developed from the QAPP and be based on expected achievements. Quarterly status reports are due to DCR for the preceding three-month period, specifically:

- May 1st for the period January 1 – March 31;
- August 1st for the period April 1 – June 30;
- November 1st for the period July 1 – September 30; and
- February 1st for the period October 1 – December 31.

Proponents should follow the milestone chart and highlight which achievements were expected to be met during the quarter. They should summarize the progress made during the three-month reporting period and report any setbacks encountered. The proponent should summarize the data obtained during the reporting period when available and describe any trends in the data.

The status reports will be used by DCR to track progress. If undesirable trends become evident during the testing phase, the proponents should report how they plan to respond to the assessment findings and begin identifying and implementing corrective actions. If undesirable trends become evident, DCR can call for the marketing to cease until the problem is found and fixed. The DCR will make evaluations on a case-by-case basis.

Each status report should include:

- Title of the project
- Name of proponent submitting the report
- Date of the reporting period
- Test site location
- Performance claim
- Summary of work accomplished during the reporting period
- Summary of findings, including data trends
- Summaries of contacts with representatives of the local community, public interest groups, or state/federal agencies
- Changes in key project personnel
- Projected work for the next reporting period
- Updated milestone chart

Submit an electronic version, as a CD or E-mail attachment, to DCR:

Virginia Department of Conservation and Recreation
Division of Soil and Water Conservation
Stormwater Management BMP Clearinghouse
203 Governor Street, Suite 206
Richmond, VA 23219-2094

E-mail: SWMESquestions@dcr.virginia.gov

For assistance, please contact DCR's Virginia Stormwater Management Program.

E-mail: SWMESquestions@dcr.virginia.gov

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Appendix A -- Number of Tests

Slightly Modified From:

Assessing Performance of Manufactured Treatment Devices:
State of the Science and Review of Proposed Virginia Testing Protocols

Expert Panel Report Prepared for:

Virginia Department of Conservation and Recreation

Prepared by:

David Sample (Editor)
Department of Biological Systems Engineering
Virginia Tech

Allen Davis
Department of Civil and Environmental Engineering
University of Maryland

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Rob Roseen
Stormwater Research Center
University of New Hampshire

John Sansalone
Department of Environmental Engineering
University of Florida

Submitted:

December 13, 2010

Number of Tests

Determining the number of samples required to evaluate the performance of a stormwater treatment device is not a trivial task. Both rainfall flows/volumes and water quality will vary significantly spatially and temporally. Several statistical expressions are available in the literature for estimating sample size requirements for experimental studies. These expressions require assumptions based on an assumed level of confidence, usually upfront estimates of means and/or standard deviation, assumptions of normality, and possibly other parameters.

Many of these inputs or assumptions are not met during stormwater monitoring. Flows and input phosphorus concentrations are expected to be highly variable. They will range over an order of magnitude and will not be normally distributed. To this the performance of the device is overlain. The performance of the device is expected to be variable, depending on the concentration of phosphorus, the flow rate through the facility, and possibly other variables. As a result, a simple estimate of the number of samples required to evaluate performance is not available.

An example common expression is provided by Schneider and McCuen (2006):

$$n = \left[\frac{COV(t_\alpha)}{\varepsilon} \right]^2$$

where n is the number of samples needed for a statistically valid sample population. COV is the coefficient of variation for the data set, ε is the allowable relative error, α is the degree of confidence, and t is the appropriate t -statistic for the respective α .

The NPDES Phase I stormwater database has over 3000 measured values for Total Phosphorus (Pitt 2008). The COV for total phosphorus from all land uses is 1.5. For most engineering applications, the value of α is assumed as 0.05 (5%). For a sampling program, the error should be no more than 25% (0.25). Using a simple trial and error to account for the degrees of freedom gives a required sample size of 100.

$$n = \left[\frac{1.5(1.661)}{0.25} \right]^2 = 100$$

A second, related equation is given by Pitt and has been applied to the NPDES Phase I database.

$$n = \left[\frac{COV(Z_{1-\alpha} + Z_{1-\beta})}{\varepsilon} \right]^2$$

Here, Z is the Z -score and β is the power. The other parameters are as defined as above.

A value of 0.8 is common for β . For $\alpha = 0.05$, $Z_{0.05} = 1.645$; $Z_{0.8} = 0.85$. Based on these values and the phosphorus COV and relative error discussed above, the number of samples required is:

$$n = \left[\frac{1.5(1.645 + 0.85)}{0.25} \right]^2 = 224$$

Clearly, both of these values far exceed that which can be expected for a certification process. As a result, from a practical perspective, the number of events to be monitored is set at a minimum of 24, an average of one per month over a total 2-year timeframe.

Because rainfall depth and intensity vary and the treatment is expected to vary with these rainfall parameters, the sampling program should include some larger events.

As an example, a depth-duration frequency analysis for rainfall in Virginia is presented in Table A-1. The probability of rainfall events of various depths is provided.

Table A-1. Depth-Duration Table Showing Distribution of 48,513 Events in Virginia from 8 Weather Stations

Event	Rainfall Depth (in.)					Sum
	0.01-0.1	0.1-0.25	0.25-0.5	0.5-1	> 1	
0-2 hr	0.2799	0.0510	0.0302	0.0135	0.0050	0.3796
2-3 hr	0.0344	0.0225	0.0147	0.0078	0.0027	0.0821
3-4 hr	0.0218	0.0180	0.0133	0.0072	0.0031	0.0634
4-7 hr	0.0377	0.0431	0.0380	0.0226	0.0087	0.1502
7-13 hr	0.0149	0.0356	0.0500	0.0468	0.0218	0.1691
13-24 hr	0.0014	0.0086	0.0236	0.0422	0.0393	0.1151
>24 hr	0.0000	0.0004	0.0023	0.0102	0.0276	0.0405
Sum	0.3901	0.1791	0.1722	0.1502	0.1083	1

Based on these distributions, the following rainfall depths can be expected from various sample population sizes (Table A-2):

Table A-2. Distribution of Average Rainfall Event Depth by Sample Size¹

Sample Size	Rainfall Depth (in.) ²			
	0.1<X<0.25	0.25-0.5	0.5-1	> 1
15	3.4	3.9	4.2	3.5
18	3.9	4.7	5.3	4.2
20	4.3	5.0	5.9	4.7
24	5.2	6.2	6.6	6.0
30	6.5	7.5	8.3	7.6
60	12.7	15.5	15.8	14.8

¹ Table based upon methods adapted by Schneider and McCuen 2006, and Kreeb 2003, supplemented with data from Virginia and including a Monte Carlo model of the sampling program.

² Events less than 0.1 inches have been removed due to sampling program requirements. Events less than 0.1 inches constituted approximately 13-15% of events for each set.

Events will vary based upon when they are measured and collected due to climatic variability. Thus, these example depths are provided as a comparative assessment of how representative the submitted sampled regime actually was.

References:

Kreeb, L.B. 2003. Hydrologic Efficiency and Design Sensitivity of Bioretention Facilities. Honor's Research, Univ. of Maryland, College Park, MD.

Schneider, L.E. and R.H. McCuen. 2006. Assessing the hydrologic performance of best management practices. *Journal of Hydrologic Engineering* 11(3): 278-281.

Appendix B -- List of Parameters for Sampling

Slightly Modified From

The Technology Aceptance Reciprocity Partnership

Protocol for

Stormwater Best Management Practice
Demonstrations

Updated: July 2003

DRAFT

List of Parameters for Sampling

Pollutant	Target Pollutant	Incidental Pollutant	Not Addressed
SOLIDS			
• Floating solids and debris			
• 0.062 mm – 0.0250 mm			
• 0.250 mm – 1.0 mm			
• Larger than 1.0 mm			
• Total Suspended Solids			
• BOD, COD, TOC, TDS			
• Hydrocarbons			
• Oil & Grease			
• TPH by IR			
• Total PAH			
• Floating oil			
METALS			
• Copper (total/dissolved)			
• Lead (total/dissolved)			
• Zinc (total/dissolved)			
• Chromium (total/dissolved)			
• Cadmium (total/dissolved)			
• Other (e.g., cyanide, nickel)			
NUTRIENTS			
• Total Phosphorus			
• Total Soluble Phosphorus			
• Nitrate/nitrite			
• Ammonium			
• Total Kjeldahl nitrogen			
• Total nitrogen			
BACTERIA (<i>E. coli</i> , total coliform), Enterococci			
TEMPERATURE EFFECTS			

Appendix C – Particle-Size Distribution

Slightly modified from

Guidance for Evaluating Emerging
Stormwater Treatment Technologies
Technology Assessment Protocol – Ecology
(TAPE)

January 2008 Revision

Publication Number 02-10-037

Washington State Department of Ecology

Particle-Size Distribution

Wet sieve protocol and mass measurement

(Recommended by the Technical Review Committee [TRC] that serves in an advisory capacity to provide recommendations to Washington State Department of Ecology)

The intent of providing this protocol is to allow more analytical flexibility for vendors while setting reasonable expectations in terms of results. The purpose of requiring particle-size distribution (PSD) analysis in the TAPE protocols is to collect consistent information on particle size that will aid in evaluating system performance. PSD measurements will provide a frame of reference for comparing variability in performance between storms and between different sites. These measurements are an important tool with which to assess performance because performance is likely to be affected by particle size. For example, it is likely that performance will drop with a substantial increase in fine soil particles. Conversely, it is anticipated that performance will be high with sandy sediments.

This protocol is intended for use with the laser diffraction particle-size distribution (PSD) analysis. Laser diffraction methods are effective for particles smaller than 250 μm . Therefore, particles greater than 250 μm must be removed with a sieve prior to PSD analysis. These larger-sized particles will be analyzed separately to determine the total mass of particulates greater than 250 μm . This protocol functions as a supplement to the existing protocols provided by the manufacturers of laser diffraction instruments such that the larger-sized particles in the sample can also be measured.

The mass measurement for the larger-sized particles will also separate out particles between 499 to 250 μm in order to be consistent with the *Guidance for Evaluating Emerging Stormwater Treatment Technologies* definition of TSS (total suspended particles <500 μm).

NOTE: The Technical Review Committee (TRC) recognizes the fact that applying a mathematical constant for density would provide a rough estimate of mass. However, there is concern that the potential error associated with the results due to different soil types and structure might be large.

Wet Sieving and Mass Measurement for Laser Diffraction Analysis

Wet sieving

Sample Collection/Handling

Samples should be collected in HDPE or Teflon containers and held at 4°C during the collection process. If organic compounds are being collected, the sample containers should be glass or Teflon.

Preservation/holding time

Samples should be stored at 4°C and must be analyzed within 7 days (U.S. EPA 1998). Samples may not be frozen or dried prior to analysis, as either process may change the particle-size distribution.

Sonication

Do not sonicate samples prior to analysis to preserve particle integrity and representativeness. Laboratories using laser diffraction will have to be notified not to sonicate these samples at any time during the analysis. This request is to be written on the chain-of-custody form that the analytical laboratory receives in order to assure that sonication is omitted.

Laboratory Procedures

Equipment

- 2 L of stormwater sample water (total sample required for analysis [ASTM 1997, D 3977])
- Drying oven (90°C ± 2 degrees)
- Analytical balance (0.01 mg accuracy)
- Desiccator (large enough diameter to accommodate sieve)
- Standard sieves – larger than 2" diameter may be desirable
- 500 µm (Tyler 32, US Standard 35)
- 250 µm (Tyler 60, US Standard 60)
- Beakers – plastic (HDPE)
- Funnel (HDPE – Large enough diameter to accommodate sieve)
- Wash bottle
- Pre-measured reagent-grade water

Sample processing

- Dry 250 µm and 500 µm mesh sieves in a drying oven to a constant weight at 90 ± 2°C.
- Cool the sieves to room temperature in a desiccator.
- Weigh each sieve to the nearest 0.01 mg.
- Record the initial weight of each dry sieve.
- Measure the volume of sample water and record.
- Pour the sample through a nested sieve stack (the 500 µm sieve should be on the top and the sieve stack should be stabilized in a funnel and the funnel should be resting above/inside a collection beaker).
- Use some of the pre-measured reagent-grade water in wash bottle to thoroughly rinse all soil particles from sample container so that all soil particles are rinsed through the sieve.

- Thoroughly rinse the soil particles in the sieve using a pre-measured volume of reagent-grade water.
- The particles that pass through the sieve stack will be analyzed by laser diffraction particle-size distribution (PSD) analysis using the manufacturers recommended protocols (with the exception of no sonication).
- Particles retained on the sieve (>250 µm) will not be analyzed with the laser diffraction PSD.
- Dry each sieve (500 µm and 250 µm) with the material it retained in a drying oven to a constant weight at $90 \pm 2^\circ\text{C}$. The drying temperature should be less than 100°C to prevent boiling and potential loss of sample (PSEP 1986).
- Cool the samples to room temperature in a desiccator.
- Weigh the cooled sample with each sieve to the nearest 0.01 mg.
- Subtract initial dry weight of each sieve from final dry weight of the sample and sieve together.
- Record weight of particles/debris separately for each size fraction (> 500 µm and 499 – 250 µm).
- Document the dominant types of particles/debris found in this each size fraction.

Laser diffraction (PSD)

PSD results are reported in mm/L for each particle-size range. Particle-size gradations should match the Wentworth grade scale (Wentworth 1922).

Mass Measurement

Equipment

- Glass filter – 0.45 µm (pore size) glass fiber filter disk (ASTM 1997, D 3977) (larger diameter sized filter is preferable)
- Drying oven ($90^\circ\text{C} \pm 2$ degrees)
- Analytical balance (0.01 mg accuracy)
- Wash bottle
- Reagent-grade water

Procedure

- Dry glass filter in drying oven at $90 \pm 2^\circ\text{C}$ to a constant weight.
- Cool the glass filter to room temperature in a desiccator.
- Weigh the 0.45 µm glass filter to the nearest 0.01mg.
- Record the initial weight of the glass filter.
- Slowly pour the laser diffraction sample water (after analysis) through the previously weighed 0.45 µm glass filter and discard the water.
- Use reagent-grade water in wash bottle to rinse particles adhering to the analysis container onto glass filter
- Dry glass filter with particles in a drying oven at $90 \pm 2^\circ\text{C}$ to a constant weight.
- Cool the glass filter and dried particles to room temperature in a desiccator.
- Weigh the glass filter and particles to the nearest 0.01mg.
- Subtract the initial glass filter weight from the final glass filter and particle sample weight.
- Record the final sample weight for particles <250 µm in size.

Quality Assurance

Dried samples should be cooled in a desiccator and held there until they are weighed. If a desiccator is not used, the particles will accumulate ambient moisture and the sample weight will be overestimated. A color-indicating desiccant is recommended so that spent desiccant can be detected easily. Also, the seal on the desiccator should be checked periodically, and, if necessary, the ground glass rims should be greased or the "O" rings should be replaced.

Handle sieves with clean gloves to avoid adding oils or other products that could increase the weight. The weighing room should not have fluctuating temperatures or changing humidity. Any conditions that could affect results such as doors opening and closing should be minimized as much as possible.

After the initial weight of the sieve is measured, the sieve should be kept covered and dust free. Duplicate samples should be analyzed on 10% of the samples for both wet sieving and mass measurements.

Reporting

Visual observations should be made on all wet sieved fractions and recorded. For example if the very coarse sand fraction (2,000-1,000 μm) is composed primarily of beauty bark, or cigarette butts, or other organic debris this should be noted. An option might also be for a Professional Geologist to record the geological composition of the sediment as well.

References

- ASTM. 1997. *Standard Test Methods for Determining Sediment Concentration in Water Samples*. Method D 3977. American Society for Testing and Materials, Philadelphia, PA.
- Puget Sound Estuary Program (PSEP). 1986. *Recommended Protocols for Measuring Conventional Sediment Variables in Puget Sound*. Prepared by Tetra Tech, Inc. for U.S. Environmental Protection Agency and Puget Sound Water Quality Authority. Tetra Tech Inc., Bellevue, WA.
- U.S. EPA. 1998. *Analysis of Total Suspended Solids by EPA Method 160.2*. Region 9, Revision 1. SOP 462. 12 pp.
- Wentworth, C.K. 1922. A scale of grade and class terms for clastic sediments. *Journal of Geology* 30: 377-392.

Appendix D -- Laboratory Methods

Slightly modified from

Guidance for Evaluating Emerging

Stormwater Treatment Technologies

Technology Assessment Protocol – Ecology
(TAPE)

January 2008 Revision

Publication Number 02-10-037

Laboratory Methods

Table: Examples of analytical procedures and reporting limits used in stormwater monitoring

Parameter	Analyte (or surrogate)	Method (in water)	Reporting Limit ^{a, b}
Conventional parameters	Total suspended solids	SM 2540D	1.0 mg/L
	Total dissolved solids	SM 2540C	1.0 mg/L
	Settleable solids	SM 2540F	1.0 mg/L
	Total Volatile Solids	EPA Method 160.4	1.0 mg/L
	Suspended Sediment Concentration	ASTM Method D3977-97	1.0 mg/L*
	Particle size distribution	Coulter Counter or Laser diffraction, or comparable method	NA
	Grain-size	Ecology method sieve and pipette (PSEP 1997), or comparable method	NA
	pH	EPA Method 150.1 or SM 4500H ⁺	0.2 units
Hardness as CaCO ₃	EPA Method 130.1 or SM 2340B	1.0 mg/L*	
Nutrients	Total phosphorus	EPA Method 365.3 or SM 4500-P E	0.001 mg/L
	Orthophosphate	EPA Method 365.3	0.003 mg/L
	Total kjeldahl nitrogen	EPA Method 351.2	1.0 mg/L
	Nitrate-Nitrite	EPA Method 353.2 or SM 4500 -NO ₃ ⁻ F	0.01 mg/L
Metals	Total recoverable zinc	EPA Method 200.8 (ICP/MS)	5.0 µg/L
	Dissolved zinc	EPA Method 200.8 (ICP/MS)	1.0 µg/L
	Total recoverable lead	EPA Method 200.8 (ICP/MS)	0.1 µg/L
	Dissolved lead	EPA Method 200.8 (ICP/MS)	0.02 µg/L
	Total recoverable copper	EPA Method 200.8 (ICP/MS)	0.1 µg/L
	Dissolved copper	EPA Method 200.8 (ICP/MS)	0.1 µg/L
	Total recoverable cadmium	EPA Method 200.8 (ICP/MS)	0.1 µg/L
	Dissolved cadmium	EPA Method 200.8 (ICP/MS)	0.02 µg/L
Petroleum hydrocarbons	NWTPH-Dx	Ecology, 1997, (Publication No. 97-602) or EPA SW-846 method 8015B	0.1 mg/L
	NWTPH-Gx	Ecology, 1997, (Publication No. 97-602)	0.12 mg/L
Toxicity	<i>Daphnia pulex</i>	EPA Method 600/4-90/027F (acute)	NA
	<i>Ceriodaphnia dubia</i>	EPA Method 600/4-90/027F (acute)	NA

^a Reporting limits established as per Manchester Environmental Laboratory Users Manual (Ecology, 2005). Reporting limits for your lab 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.

*Reporting limits are based on similar methods because Manchester Lab does not conduct particular method.

Parameter	Analyte (or surrogate)	Method (in Sediment)	Reporting Limit^{a, b}
Grain-size	Total solids Total Volatile Solids Grain-size	EPA Method 160.3 or SM 2540B EPA Method 160.4 or SM 2540E Ecology Method Sieve and Pipet (PSEP 1997) or ASTM F312-97	NA 0.1%
Metals	Total recoverable zinc Total recoverable lead Total recoverable copper Total recoverable cadmium	EPA Method 200.8 (ICP/MS) or SM 3125 (ICP/MS) or EPA Method 200.7 (ICP) EPA Method 200.8 (ICP/MS) or SM 3125 (ICP/MS) EPA Method 200.8 (ICP/MS) or SM 3125 (ICP/MS) EPA Method 200.8 (ICP/MS) or SM 3125 (ICP/MS)	5.0 mg/Kg 0.1 mg/Kg 0.1 mg/Kg 0.1 mg/Kg
Petroleum hydrocarbons	NWTPH-Dx	Ecology, 1997 (Publication No. 97-602) or EPA SW-846 method 8015B	25.0-100.0 mg/Kg
Toxicity	<i>Daphnia pulex</i> <i>Ceriodaphnia dubia</i>	EPA Method 600/4-90/027F (acute) EPA Method 600/4-90/027F (acute)	NA NA

^a Reporting limits established as per Manchester Environmental Laboratory Users Manual (Ecology, 2005). Reporting limits may vary with each lab. Reporting limits for your lab should be the same or below those given in the table.

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

NA – Not applicable

SM – Standard Methods

PSEP – Puget Sound Estuary Program

ICP/MS – Inductively Coupled Plasma/Mass Spectrometry

Appendix E -- Use Designation Application Form

Questions on the form are included within this document for informational purposes only.

To complete the official form, download it from the
Virginia Stormwater Best Management Practices Clearinghouse:

www.vwrrc.vt.edu/swc

Use Designation Application Form

Project Title:

MTD Name: Today's Date:

1 Basic Technology Information

Proponent of the BMP

Company name:

Address – Street: City: State: Zip:

Proponent Contact

Name (to whom questions should be addressed):

Address – Street: City: State: Zip:

Phone number:

Fax number:

E-mail address:

BMP Technology

BMP common (marketing) name:

Specific size/capacity of BMP assessed:

Drainage area ranges served by BMP:

2 Use Designation Currently Sought (check only one)

- Pilot Use (PUD)
- Conditional Use (CUD)
- General Use (GUD)

3 Treatment for which the Technology is Designed (check all that apply)

- Stormwater Runoff Volume Reduction
- Stormwater Runoff Peak Rate Control
- Stormwater Runoff Quality Control

4 Warranty Information (describe or attach details)

5 BMP History

How long has this specific model/design been on the market?

List several locations of this exact model/size installed in Virginia (provide town and county or city and permitting authority. If known, provide latitude & longitude):

List several locations of this exact model/size installed outside Virginia if testing was performed at the site (provide location, and if known, provide latitude & longitude):

6 Technology Intended Application (check all that apply)

- Pre-treatment for downgradient BMP
- Water quality treatment
- Flood control
- Channel protection
- Other:

7 Basis for Treatment (check all that apply and fill in blanks)

- Volume-based** (captures & treats Water Quality Volume [WQV]) – Specify WQV: cubic feet
- Flow rate-based** (provides treatment up to a set rate of flow) – Specify treatment flow rates and hydrologic methods used. Specify the flow rates that are treated and provide documentation:
 - i. All flows up to the year, 24-hour storm event.
 - ii. Peak flows associated with water quality storm event (inches of rainfall; cfs)
 - iii. Other (specify):

If flow rate-based system, specify design features to prevent resuspension of captured particles/pollutants:

- Other** (describe):

8 Water Quality Treatment Mechanisms (check all that apply and provide brief description)

- Sedimentation/settling:
- Infiltration:
- Filtration (specify filter media):
- Adsorption/cation exchange:
- Chelation/precipitation:
- Chemical treatment:
- Biological uptake:
- Other (describe):

9 Design Features of Interest (answer each of the following questions.)

Pre-treatment/removal of larger particles achieved via which of the following?

- No pre-treatment
- Internal settling/sedimentation chamber
- Upgradient (separate) settling/sedimentation device
- Other (describe):

By-pass/diversion of larger flows (not designed for treatment) via which of the following?

- No by-pass/diversion
- Internal by-pass verified to prevent re-suspension captured particles/pollutants during larger flows
- Upgradient flow splitter used to divert water quality storm to device
- Other (describe):

10 Independent Performance Certification (check all that apply)

Has the BMP been "certified or performance verified" by any of the organizations below?

- No** (skip to next question)
- Yes**; Continue below and include date of certification.
 - State Agency** (list):
 - Approved (date awarded:)
 - Performance certified (date certified:)
 - Status pending
 - Other (explain):
 - TARP** (NJ only)
 - Approved:
 - Tier I (date awarded:)
 - Tier II (date awarded:)
 - Performance verified via NJCAT:
 - Other (explain):
 - TAPE** (WA State only)
 - Approved:
 - PLD - Pilot Level Designation (date awarded:)
 - CUD - Conditional Use Designation (date awarded:)
 - GULD - General Use Level Designation (date awarded:)
 - Performance Certified (date certified:)
 - Status pending
 - Other (explain):
 - Other** (provide documentation of testing protocol, status of BMP and results of testing):

11 Vendor-initiated Performance Testing (check all that apply):

Has the BMP been tested and its performance reported?

- Laboratory Tested**
 - Manufacturer (directly tested)
 - Contractor retained by manufacturer (Contact name and organization:)
 - Tested by third party (e.g., not associated or tied financially to manufacturer) (Contact name and organization:)
- Field Tested**
 - Manufacturer (directly tested)
 - Contractor retained by manufacturer (Contact name and organization:)
 - Tested by third party (e.g., not associated or tied financially to manufacturer) (Contact name and organization:)

12 Results of Vendor-initiated Performance Testing

Has the BMP been tested for pollutants of concern? (Check all that apply) **Note: Water quality certification in Virginia is awarded only for TP removal at this time.**

Phosphorus; please specify if lab or field results and then summarize the results:

Removal rates for phosphorus based upon measured:

- Total Phosphorus (TP)
 - Particulate Phosphorus (PP)
 - Total Soluble Phosphorus (TSP)
 - Soluble Reactive Phosphorus (SRP)
 - Soluble Unreactive Phosphorus (SUP)

Check here if reported % removal, load reduction, and/or effluent concentrations are provided over a range of influent concentrations, and list the range of influent concentrations:

Note: The information about the following pollutants will not be used to determine water quality certification in Virginia. Water quality certification in Virginia is awarded only for TP removal at this time.

Sediment; please specify if lab or field results and then summarize the results:

Removal rates for sediment based upon:

- Total Suspended Solids (TSS)
- Suspended Sediment Concentration (SSC)

Check here if reported % removal, load reduction, and/or effluent concentrations are provided over a range of influent concentrations, and list the range of influent concentrations:

Nitrogen; please specify if lab or field results and then summarize the results:

Specify what form(s) of nitrogen the removal rates are based upon (e.g., Total Nitrogen [TN], Total Kjeldahl nitrogen [TKN], Total Ammonia-N, Nitrate-N, Nitrite-N, etc.):

Check here if reported % removal, load reduction, and/or effluent concentrations are provided over a range of influent concentrations, and list the range of influent concentrations:

Oil/Grease; please specify if lab or field results and then summarize the results:

Check here if reported % removal, load reduction, and/or effluent concentrations are provided over a range of influent concentrations, and list the range of influent concentrations:

Heavy metals; please specify if lab or field results and then summarize the results:

Check here if reported % removal, load reduction, and/or effluent concentrations are provided over a range of influent concentrations, and list the range of influent concentrations:

Bacteria; please specify if lab or field results and then summarize the results:

Check here if reported % removal, load reduction, and/or effluent concentrations are provided over a range of influent concentrations, and list the range of influent concentrations:

Organic toxicants; please specify if lab or field results and then summarize the results:

Check here if reported % removal, load reduction, and/or effluent concentrations are provided over a range of influent concentrations, and list the range of influent concentrations:

Other; please specify if lab or field results and then summarize the results:

Check here if reported % removal, load reduction, and/or effluent concentrations are provided over a range of influent concentrations, and list the range of influent concentrations:

13 Particle-Size Distribution (PSD)

If laboratory test results are included and TSS/SSC results are reported, was Sil-Co-Sil 106 used in the test runs?

- Yes
 No -- If no, explain what was used instead:

If laboratory test results are included and TSS/SSC results are reported, was the NJDEP PSD (1 to 1,000 micron PSD) used in the test runs?

- Yes
 No -- If no, explain what was used instead:

What method and equipment were used to determine PSD?

If the method or equipment used to determine PSD differed for any lab test/storm where PSD was measured, provide the date of the test/storm and describe the change.

If laboratory test results are included, were the influent and effluent analyzed for PSD and reported for at least five (5) test runs?

- Yes
 No -- If no, explain why not:

If field test results are included, were the influent and effluent analyzed for PSD and reported for at least five (5) storms?

- Yes
 No -- If no, explain why not:

If field test results are included, did the PSD measurements that were reported include at least one storm that had 10 or more consecutive dry days before the storm?

- Yes
 No -- If no, explain why not:

If field test results are included, did the PSD measurements that were reported include at least one storm that had only 1-dry day before the storm?

- Yes
 No -- If no, explain why not:

Did the influent contain at least 50% of its particles in the 10-60 μm size range for lab tests/storms where PSD was measured?

- Yes -- Provide the percentage of particles in the 10-60 μm size range:
 No -- Provide date(s) and characteristics of lab test/storms not meeting this target and list the percentage of particles in the 10-60 μm size range for the influent:

Did the effluent contain less than 10% of its particles between 10-60 μm in size for any lab tests/storms where PSD was measured?

- Yes -- Provide the percentage of particles in the 10-60 μm size range:
 No -- Provide date(s) and characteristics of storms not meeting this target and list the percentage of particles in the 10-60 μm size range for the effluent:

14 Maintenance Considerations (check all that apply and briefly explain maintenance procedures/standards)

What is the generic inspection and maintenance plan/procedure? (attach necessary documents):

Is there a maintenance track record/history that can be documented?

- No, no track record.
 Yes, track record exists; (provide list of local or regional BMPs currently in use and maintenance track record info):

What is the expected maintenance frequency, per year?

i. Total life expectancy of BMP and, if relevant, media:

ii. For media or amendments functioning based on cation exchange or adsorption, how long will the media last before breakthrough (indicator capacity is nearly reached) occurs?

iii. For media or amendments functioning based on cation exchange or adsorption, how has the longevity of the media or amendments been quantified prior to breakthrough (attach necessary performance data or documents)?

Maintenance contract and associated costs offered by:

- Vendor – Provide current costs:
 Other commercial entities -- Provide range of current costs:

Is the maintenance procedure and/or are materials/components proprietary?

- Yes, proprietary;
 BMP lends itself to competitive bidding for maintenance
 Recourse / options exist if the vendor goes out of business
 No, not proprietary;
Are local certified contractors available?
 Yes; provide a list of companies and cities where located.
 No; local contractors are not available
Does the BMP lend itself to competitive bidding for maintenance?
 Yes; provide a list of local, certified, maintenance companies and cities where located.
 No; local competitive bidding not possible because only one maintenance company certified locally.

Maintenance complexity (Check all that apply):

- Confined space training required for maintenance
 Liquid pumping and transportation
Specify method:
Specify certified disposal locations:
 Solids removal and disposal
Specify method:
Specify certified disposal locations:

Other noteworthy maintenance parameter (describe):

15 Comments

Include any additional explanations or comments:

Appendix F -- Treatment Efficiency Calculation Methods

Modified from

Center for Watershed Protection's

Tool 8: BMP Performance Verification Checklist Appendices
2008

DRAFT

Treatment Efficiency Calculation Methods

The pollutant removal efficiency of a BMP refers to the pollutant reduction that is achieved by comparing the influent and effluent of a BMP or treatment train. Pollutant reduction can be determined on either a concentration or load/mass basis and is typically expressed as a percentage.

Concentration-based methods use the ratio of pollutant concentrations or event mean concentrations (EMCs) at the outflow to pollutant concentrations or EMCs at the inflow as the basis for calculating BMP efficiency. As a general rule, concentration-based methods often result in slightly lower performance efficiencies than mass-based methods. This may be attributed to the fact that BMPs that reduce runoff volume are also reducing pollutant loads, but a concentration-in versus concentration-out study does not account for water losses that occur through infiltration and evapotranspiration, or storage within the BMP. For this reason, the pollutant removal efficiency of these types of BMPs may be under-reported using concentration-based methods.

Mass-based methods use pollutant loads as the basis for calculating BMP efficiency. Pollutant load is the total amount of a pollutant conveyed over a specified duration. The pollutant loading from a given storm can be estimated using pollutant EMCs and flow data. Mass-based methods are influenced by the volume of water entering the BMP and water losses within the BMP (e.g., evapotranspiration and infiltration), so they are more accurate for BMPs that reduce runoff volume (Winer 2000).

The Efficiency Ratio method and the Summation of Loads methods are recommended for use by ASCE and EPA (2002) and DCR. Use of either method should be supplemented with an appropriate statistical test indicating if the differences in mean EMCs between the outflow and inflow are statistically significant.

References

- American Society of Civil Engineers (ASCE) and United States Environmental Protection Agency (EPA). 2002. *Urban Stormwater BMP Performance Monitoring: a Guidance Manual for Meeting the National Stormwater BMP Database Requirements*. EPA-821-B-02-001. Office of Water, U.S. Environmental Protection Agency, Washington DC. <http://water.epa.gov/scitech/wastetech/guide/stormwater/monitor.cfm> (accessed January 14, 2011).
- Center for Watershed Protection (CWP). 2008. *Tool 8: BMP Performance Verification Checklist Appendices*. CWP, Ellicott City, MD. 20 pp. <http://www.cwp.org> (accessed January 14, 2011).
- Winer, R. 2000. *National Pollutant Removal Database for Stormwater Treatment Practices*. Second edition. Center for Watershed Protection, Ellicott City, MD.

Methods to Estimate BMP Efficiency (from Center for Watershed Protection 2008; compiled from ASCE and U.S. EPA 2002)

Method	Type of Method	Formula	Comments
Efficiency Ratio (ER)	Concentration	$ER = 1 - \frac{\text{Average outlet EMC}}{\text{Average inlet EMC}}$ <p>Where the EMC = $\frac{\sum_{j=1}^n C_i V_i}{\sum_{j=1}^n V_i}$</p> <p>Where: C_i = event inflow concentration; V_i = event inflow volume</p>	<ul style="list-style-type: none"> • Most useful when loads are directly proportional to the storm volume. • Weights EMCs from all storms equally. • The accuracy varies with BMP type. • Minimizes impacts of smaller/cleaner storms on performance calculations. • Can apply log normalization to avoid equal weighting of events.
Summation of Loads (SOL)	Mass	$SOL = \frac{\text{sum of outlet loads}}{\text{sum of inlet loads}}$ <p>Where the Load = CN_i</p> <p>C_i = average concentration within period i; V_i = volume of flow during period i</p>	<ul style="list-style-type: none"> • Loads are calculated using concentration and flow volume and are summed for the number of events measured. • A small number of large storms can significantly influence results. • Removal of material is most relevant over entire period of analysis • Uses a mass balance approach. • Effluent concentration may still be high despite high removal efficiency

Appendix G -- Stormwater BMP Demonstration Site Summary

Modified From

The Technology Aceptance Reciprocity Partnership

Protocol for

Stormwater Best Management Practice
Demonstrations

Updated: July 2003

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Questions on the form are included within this document for informational purposes only.

To complete the official form, download it from the

Virginia Stormwater Best Management Practices Clearinghouse:

www.vwrrc.vt.edu/swc

Stormwater BMP Demonstration Site Summary

Download this form from the Virginia Stormwater Best Management Practices Clearinghouse (www.vwrrc.vt.edu/swc), complete it for each testing site, and submit in electronic format as part of the Use Designation Application.

Technology Name

Technology Category (e.g., Structural, Non-structural; Detention Pond, Sand Filter)

Date

1. Contact Information

Vendor Name

Contact Name

Address (Street, City, State, Zip)

Address (Street, City, State, Zip)

Phone, Fax, E-mail Address

2. Test Site Information

Site Name

Address (Street, City, State, Zip)

Land Use: Commercial/Office, Residential, Industrial, Open, Other (Specify)

Total Contributing Drainage Area

Particle-Size Distribution of Sediments in Tests (Entire Distribution, Specify D_{50})

3. Watershed Information

Watershed Name

Total Watershed Area

Percent of Impervious Area in Watershed

4. Precipitation Information

Regional Climate Station

Average Number of Storms Year

Average Annual Rainfall (in.)

Monthly Average Rainfall at Test Site (During Testing) (in.)

5. BMP Testing Information

Date System Installed

Insert tables that document the following information:

Dates BMP Tested/Sampled

Storm Events Start and End Times (During Testing)

Testing Start and End Times (For Each Event)

Storm Precipitation (For Each Event) (in.)

Total Storm Flow Volume into BMP (For Each Event) (ft.³)

Total Storm Flow Volume Bypassed (For Each Event) (ft.³)

Type of Samples Collected (e.g., Flow-weighted, Composite)

Parameters and Units Measured

Analysis Method