Guidance for Evaluating Stormwater Manufacture Treatment Devices

Virginia Technology Assessment Protocol (VTAP)

Prepared by:

Virginia Department of Conservation and Recreation

in cooperation with:

Virginia Stormwater Best Management Practice Clearinghouse Committee

You can print or download this document from the following websites:
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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
C – Celsius
CAD – computer-aided design
Clearinghouse – Virginia Stormwater BMP Clearinghouse
CUD – Conditional Use Designation
D_{50} – mass median particle diameter (μm)
DCLS – Division of Consolidated Laboratory Services
DCR – Virginia Department of Conservation and Recreation
Department – Virginia Department of Conservation and Recreation
DGS – Department of General Services
Director – Department Director
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"
ft./sec. – feet per second
ft.^{3} – cubic feet
ft.^{3}/sec. – cubic feet per second
GIS – geographic information system
GUD – General Use Designation
HASP – health and safety plan
HDPE – high-density polyethylene
hr – hour
ICP/MS – inductively coupled plasma/mass spectrometry
i.e. – Latin *id est*, "that is"
in. – inches
in./hr. – inches per hour
Inc. – Incorporated
mg – milligram (one thousandth of a gram)
mg/kg – milligrams per kilogram
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
NELAP – National Environmental Laboratory Accreditation Program
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
NWTPH-Dx – Northwest Total Petroleum Hydrocarbons-Motor Oil and Diesel fractions
O&M – operation and maintenance
PAH – polycyclic aromatic hydrocarbons
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
SW – Solid Waste
TAPE – Technology Assessment Protocol – Ecology
TARP – Technology Acceptance Reciprocity Partnership
TER – technology evaluation report
TKN – total Kjeldahl nitrogen
TMDL – Total Maximum Daily Load
TN – total nitrogen
TNI – The NELAC Institute
TP – total phosphorus
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
VPDES – Virginia Pollutant Discharge Elimination System
VTAP – Virginia Technology Assessment Protocol
V_Vt_V – Variable Volume – Variable Time
VWRRC – Virginia Water Resources Research Center
WA – Washington
WEF – Water Environment Federation
WSDOE – Washington State Department of Ecology

1 -- Introduction

This document, the *Virginia Technology Assessment Protocol* (VTAP), describes the assessment process for listing stormwater manufactured treatment devices (MTDs) on the Virginia Stormwater Best Management Practice (BMP) Clearinghouse website: http://www.vwrrc.vt.edu/swc. For this document, MTDs refer to pre-fabricated BMPs used to remove pollutants from stormwater runoff; MTD designs may involve proprietary components or processes. MTDs may not be installed in Virginia for the treatment of stormwater runoff quality control credit (i.e., phosphorus removal) unless approved by the Virginia Department of Conservation and Recreation (DCR), referred to in this document as the "Department," through the VTAP process and listed on the Clearinghouse website. This process was developed by the Department in collaboration with the Virginia Stormwater BMP Clearinghouse Committee (Clearinghouse Committee) and approved by the Virginia Soil and Water Conservation Board.

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 4 VAC 50-60 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* the Department*)] . . . any of the powers and duties vested in it by [the law] . . . ."* (§10.1-603.2:1.2). The Virginia Soil and Water Conservation Board and the Department thus maintain the authority to establish, approve, and update design specifications of BMPs that may be used within Virginia to control stormwater runoff.

The *Virginia Administrative Code* states that BMPs not listed in 4 VAC 50-60-65 (water quality compliance) "shall be reviewed and approved by the director [of the Department] in accordance with procedures established by the BMP Clearinghouse Committee and approved by the board [Virginia Soil and Water Conservation Board]." Accordingly, this guidance document sets forth procedures established by the Clearinghouse Committee and was approved by the Virginia Soil and Water Conservation Board.

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

The purpose of the VTAP is to define the procedures to follow for approving and listing MTDs on the Virginia Stormwater BMP Clearinghouse website. Because the water-quality regulatory criterion in the Virginia Stormwater Management Program (4 VAC 50-60-63) is aimed at removal of total phosphorus (TP), TP removal provides the basis for water-quality testing in Virginia. This document is, therefore, for the purpose of assessing MTDs that remove phosphorus from post-construction stormwater runoff.

Approved MTDs assessed for phosphorus removal through the VTAP process shall be listed on the BMP Clearinghouse website and shall be assigned pollutant removal (PR) credits for TP.

The PR credits approved through the VTAP and listed on the Clearinghouse website shall be the ones that state agencies and local stormwater management programs shall recognize when the approved MTDs are included in stormwater management plans in Virginia.

Local governments statewide can apply the use designations listed on the Clearinghouse website to evaluate the suitability of these BMPs for use in their communities. Furthermore, information acquired during testing may also be useful for the development and implementation of Total Maximum Daily Loads (TMDLs).

1.3 -- Applicability

This protocol is intended for use in assessing MTDs for use in Virginia to treat post-construction, stormwater runoff. The testing protocol is intended for volume-based and flow-rate based stormwater MTDs and is not suitable for all stormwater treatment practices. This testing protocol does NOT apply to non-proprietary BMPs, and the protocol is NOT for use in the evaluation of erosion and sediment control technologies or products. Although documents that support the Technology Acceptance Reciprocity Partnership (TARP) (TARP 2003, NJDEP 2009) and the Technology Assessment Protocol – Ecology (TAPE) (WSDOE 2008, 2011) were used in developing this guidance, the VTAP is specific to Virginia. Approvals obtained through TARP, TAPE, or other established protocols do not eliminate the need for review and approval in Virginia. Those seeking approval in Virginia for MTDs previously approved by another state shall demonstrate consistency with the procedures articulated in this document.

1.4 -- Roles and Responsibilities

1.4.1 -- Virginia Soil and Water Conservation Board

According to the *Virginia Administrative Code* (4 VAC 50-60-65) (see **Section 1.1 -- Authority**), the Virginia Soil and Conservation Board shall establish procedures for reviewing and approving stormwater management BMPs. Thus, the Board has approved this protocol (VTAP), which is to be used to approve MTDs for use in Virginia for treating phosphorus in post-construction, stormwater runoff.

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

The Virginia Department of Conservation and Recreation (the Department) is responsible for Stormwater Management Programs in Virginia (see **Section 1.1 -- Authority**). For this reason, the Department may obtain recommendations from outside evaluators and the Clearinghouse Committee, but the Department's director, referred to in this document as the "Director," is ultimately responsible for granting or denying use designations and establishing PR credits for MTDs.

The Department of Conservation and Recreation:

- Chairs the Virginia Stormwater BMP Clearinghouse Committee;

- Grants use designations and assigns PR credits;
- Approves changes made to use designations and PR credits;
- Approves or denies requested exceptions to the VTAP,
- Reviews and approves Quality Assurance Project Plans (QAPPs);
- Reviews and approves changes to approved QAPPs;
- Provides oversight and analysis of all submittals to ensure consistency with the Department's stormwater management requirements;
- Provides responses regarding public comments received on Technology Evaluation Reports posted on the Clearinghouse website;
- Assumes the duties of the Department's evaluator(s) (see below) when necessary; and
- Reviews new information and updates the VTAP as needed.

1.4.3 --The Department's Evaluator(s)

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

The Department's evaluator(s):

- Review submitted applications for completeness;
- Provide recommendations to the Department regarding technical questions posed by the agency;
- Review QAPPs and provide recommendations to the Department for approval or denial of QAPPs;
- May periodically inspect laboratory testing and/or field testing;
- Provide secondary check of data validation;
- Provide recommendations to the Clearinghouse Committee and the Department regarding the need for additional testing (if necessary) and limitations of evaluated MTDs;
- Provide recommendations to the Clearinghouse Committee and the Director regarding PR credits to assign to MTDs and whether or not to approve MTDs at requested use-designation levels;
- Provide draft responses to the Department regarding public comments received on Technology Evaluation Reports posted on the Clearinghouse website; and
- Work in collaboration with the proponent to develop information for the Clearinghouse website regarding approved MTDs.

1.4.4 -- Clearinghouse Committee

Members of the Virginia Stormwater BMP Clearinghouse Committee that have experience with stormwater BMPs but are not affiliated with the proponent of the MTD being assessed or other stormwater MTD manufacturers/vendors shall review applications and provide recommendations to the Department. Members of the committee shall also have the opportunity to comment on quality assurance project plans (QAPPs).

The Clearinghouse Committee:

- Establishes procedures (i.e., VTAP) for approving MTDs in Virginia;
- Meets quarterly to provide oversight review of use-designation applications;

- Provides recommendations to the Department and the proponent regarding PR credits to assign to MTDs and whether or not to approve MTDs at requested use-designation levels;
- Interacts with the Department staff to assess how well the VTAP process satisfies the Department's stormwater treatment BMP selection objectives.

1.4.5 -- Virginia Water Resources Research Center

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

The Virginia Water Resources Research Center:

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

1.4.6 -- 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 MTD vendor, consultant, etc.

The proponent:

- Submits the use-designation application to the Department;
- Submits status reports to the Department;
- Submits QAPP to the Department for each field test site;
- Keeps the QAPP current and reviews it at least annually to determine if changes are necessary;
- Submits requests to change approved QAPPs, if applicable, to the Department;
- Notifies the Department of all installations made in Virginia during the testing period; and
- Works in collaboration with the Department's evaluator(s) to develop information for the Clearinghouse website regarding approved MTDs.

1.4.7 -- Proponent's Technical Advisor(s) and/or Third-Party Observer

The proponent's technical advisor provides oversight of performance testing. A third-party observer is a consultant who observes laboratory testing that is performed by the manufacturer or vendor of the MTD. The Department requires the use of a technical advisor and/or third-party observer at the onset of testing. This consultant is paid for by the manufacturer or vendor of the technology and is not provided by the Department, the Department's evaluator(s), the Clearinghouse Committee, or the VWRRC. No financial conflict of interest shall exist between the technical advisor or third-party observer and the manufacturer or vendor of the MTD (see **Section 1.5 -- Conflict of Interest**).

At a minimum, the technical advisor:

- Certifies the following components of the MTD testing: (1) QAPP, (2) oversight of QAPP implementation, and (3) Technical Evaluation Report (TER). Certification is accomplished by submitting signed statements to the Department and the manufacturer of the MTD. Certification of the TER shall state that the applicable field and/or laboratory testing protocol requirements were met or exceeded; deviations that exceed protocol requirements shall be identified in the certified statement.
- Reviews the QAPP at least annually to determine if any changes are necessary; and
- Signs conflict-of-interest statements (see **Section 1.5 -- Conflict of Interest**).

1.5 -- Conflict of Interest

No financial conflict of interest shall exist between the technical advisor or third-party observer and the manufacturer or vendor of the MTD. Financial interest can include, but is not limited to the ownership of a manufacturer, royalties from a MTD, or dividends/commission from a manufacturer. Receipt of a fee for conducting or overseeing testing from one or more manufacturers is not considered a conflict of interest. Examples of financial conflicts of interest include, but are not limited to the following:

- Having an ownership stake in the manufacturer;
- Being employed by the manufacturer or vendor;
- Receiving a commission for selling a MTD for a manufacturer or vendor;
- Having a licensing agreement with the manufacturer or vendor; or
- Receiving funding not associated with a MTD testing program or grants from the manufacturer.

A person or company who is proposed as a technical advisor or a third-party observer shall submit a disclosure record of all previous and current personal, professional, and financial relationships with the manufacturer or other MTD manufacturers. For the purposes of determining conflict of interest, the following people and entities are subject to the aforementioned clause regarding avoiding conflicts of interest, including, but not limited to: the parent company; owners; directors; employees; and immediate family members of owners, directors, and employees, of the independent test facility, third-party observer, or verification entity. The items in the disclosure record shall not be construed as conflicts of interest but rather disclosure of existing relationship to ensure transparency in the testing process. A disclosed relationship does not represent a conflict of interest when a consultant, university, or independent test facility receives fees for testing or overseeing the testing of MTDs from one or more manufacturers.

Technical advisors and third-party observers shall submit a signed conflict-of-interest statement to the Department and the manufacturer of the MTD that includes the following: (1) a statement that there was no financial conflict of interest regarding the test results, and (2) a statement that all relevant relationships were fully disclosed in the disclosure record.

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

This protocol has been published for listing manufactured treatment devices on the Virginia Stormwater BMP Clearinghouse website and for assigning pollutant removal credits for phosphorus for use in Virginia. Neither the Department; its contracted partners, including the Department's contracted evaluator(s) and the VWRRC; nor the Clearinghouse Committee accept responsibility or liability for performance of stormwater technologies being evaluated using the VTAP. Whereas the Department authorizes the installation of approved MTDs, the jurisdiction operating a local Virginia Stormwater Management Program shall have full responsibility for the decision to allow MTDs to be used in the jurisdiction. The Department and the jurisdiction shall have the ability to place conditions upon installations of approved MTDs.

Proprietary information that is not to be made public shall NOT be included in the application but instead may be submitted separately to the Department along with a completed Confidentiality and Non-Disclosure Agreement (referred to as the “Agreement” and available on the Virginia Stormwater BMP Clearinghouse website). The Department highly recommends that confidential information NOT be sent to the Department via e-mail. The Department's Stormwater Regulatory Program Manager or designee shall evaluate the confidentially and either: 1) sign the Agreement and return a copy of the signed Agreement to the proponent, or 2) deny the request. If the Agreement is signed, the information shall be considered as part of the application by the Department staff, including the Director, and may be shared with the Department's contractors associated with implementing the VTAP process, after securing an agreement from all such persons to comply with the terms and conditions of the Agreement. If the request is denied, the Department shall notify the proponent of the reason for denial and return the information to the proponent. Furthermore, if the confidentiality request is denied, such information shall not be considered by the Director in the evaluation of the MTD. At the completion of a product's testing and upon the request of the proponent, DCR shall return the proprietary information to the proponent within 30 days of the request.

2 -- MTD Use Designations

There are three use designations for assessed stormwater MTDs 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**.

Table 2.1 summarizes the testing requirements that shall be met to receive each use designation for phosphorus removal. MTDs with limited data shall only be evaluated for the **PUD**. The Department shall not consider an application for a **CUD** or a **GUD** unless the application includes sufficient field performance data that clearly demonstrate acceptable feasibility and the likelihood that the MTD will achieve desired performance levels using the manufacturer's recommended sizing criteria, pretreatment requirements, and maintenance schedule, etc.

Table 2.1. Summary of the testing requirements for phosphorus removal by stormwater manufactured treatment devices to receive Pilot Use Designation (PUD), Conditional Use Designation (CUD), and General Use Designation (GUD) in Virginia

Use Designation	Minimum Testing Required to Receive Designation	Test Parameter Required to Receive TP Approval	Accepted Protocols
PUD	1 Full-scale Lab or Field	TP or TSS or SSC	Lab: NJCAT (http://www.njcat.org/; NJDEP 2003) or other protocol accepted by the Department Field: VTAP, TARP (2003), TAPE (WSDOE 2008, 2011) or other protocol accepted by the Department
CUD	1 Field	TP	VTAP, TARP (2003), TAPE (WSDOE 2008, 2011), or other protocol accepted by the Department
GUD	2 Field	TP	At least 1 test site shall follow VTAP and other(s) shall be consistent with protocols accepted for CUD

MTDs may not be installed in Virginia for PR credit (i.e., phosphorus removal) for the treatment of post-construction stormwater runoff unless the Director grants it the official status of PUD, CUD, or the approved status of GUD (This rule does not apply to post-construction, non-proprietary BMPs). To gain official approval for the **PUD** or **CUD**, the Department's Stormwater Regulatory Program Manager or designee shall approve a QAPP for at least one field test site. A Department-approved QAPP is required for each field test site, and performance monitoring methods shall follow the approved QAPP.

Once granted an official **PUD, CUD**, or **GUD**, MTDs shall be assigned a PR credit for phosphorus removal. The PR credit is provisional for the **PUD** and **CUD**. The PR credit shall be calculated from the direct measurement of TP loads into and out of the MTD. 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.

For the purpose of awarding a use designation and establishing PR credits for MTDs, the DCR shall allow the use of test data collected in states other than Virginia. However, any field data used to receive a **GUD** shall be derived from testing sites representative of urban stormwater conditions expected in Virginia (see Table 2.2). Field data used to receive a **PUD** or **CUD** may be derived from testing sites not representative of urban stormwater conditions expected in Virginia, but if such a test site is used, the proponent shall address the likely impact of the different conditions for use in Virginia. For example, in order to receive a **CUD,** a MTD field tested in a rainfall distribution other than Type II, such as those approved in Washington's TAPE program, shall address the influence of the rainfall intensity, duration, peak flow, etc. Thus, in this example, 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 Type IA of the Pacific Northwest. Information provided in the use-designation application and/or QAPP about the demonstration site shall be used to help assess how well the site represents conditions in Virginia.
If a proponent decides to test at two different sites in Virginia (for **GUD** status), DCR will consider accepting data compiled in Virginia Beach or another Southeastern Virginia jurisdiction determined to be within the Type III rainfall distribution. However, the manufacturer will have to ensure that all the data quality objectives of the VTAP are otherwise met, and that the actual rainfall events during the testing period are not extreme or significantly outside the typical Virginia or Type II rainfall patterns.

Table 2.2. Urban stormwater test conditions for approval 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)

2.1 -- Pilot Use Designation (PUD)

The **PUD** is for the purpose of collecting field performance data according to the VTAP when the performance data do not meet the standards of applying for a **CUD** or **GUD**. The Department shall grant a **PUD** if it believes the practice has merit and additional field performance testing is needed.

A **PUD** approved for phosphorus treatment may be granted for MTDs that were tested for TSS or SSC removal in the laboratory at full-scale size using Sil-Co-Sil 106 or from field testing. To receive a **PUD**, laboratory testing shall follow the NJCAT protocol (http://www.njcat.org/; NJDEP 2003) or other laboratory protocol accepted by the Department. To receive a **PUD**, data from field testing shall follow the VTAP, TARP (2003), TAPE (WSDOE 2008, 2011) or other established protocol accepted by the Department (see Table 2.1).

MTDs with an official **PUD** from the Department shall be listed as such on the Clearinghouse website and granted a temporary pollutant removal (PR) credit for TP (not to exceed 30%). These MTDs may be installed in Virginia subject to approval by the jurisdiction operating the local Virginia Stormwater Management Program and conditions that the Department or the jurisdiction may impose. The proponent of the MTD shall notify the Department of all installations made in Virginia during the testing period. The **PUD** expires after 24 months from the time the first QAPP is approved by the Department unless the Department grants an extension of the testing period. Testing is required at one field site to move to the **CUD** level and at two field sites to move to the **GUD** level.

If a MTD approved at the **PUD** level is found to perform poorly, the Department will not require the removal of the MTDs installed in Virginia for testing purposes or otherwise installed during the testing period. However, localities have the discretion to apply conditions to the installation of BMPs within their jurisdictions.

2.2 -- Conditional Use Designation (CUD)

The **Conditional Use Designation** (**CUD**) is for MTDs that have undergone rigorous field testing in at least one location using a Department-approved protocol for testing the removal of TP from post-construction stormwater runoff. The test protocol used could be the VTAP, TARP (2003), TAPE (WSDOE 2008, 2011), or other protocol with phosphorus testing that is accepted by the Department (see Table 2.1). The Department shall grant a **CUD** if it believes the practice has merit and additional field performance testing is needed.

MTDs with an official **CUD** from the Department shall be listed as such on the Clearinghouse website and granted a temporary pollutant removal credit for TP (not to exceed 50% when non-VTAP testing protocols have been followed for earlier testing). These MTDs may be installed in Virginia subject to approval by the jurisdiction operating the local Virginia Stormwater Management Program and conditions that the Department or the jurisdiction may impose. The proponent of the MTD shall notify the Department of all installations made in Virginia during the testing period. The **CUD** expires after 24 months from the time the first QAPP is approved by the Department unless the Department grants an extension of the testing period. Testing that follows the VTAP is required at two distinct field sites for approval at the **GUD** level.

If a MTD approved at the **CUD** level is found to perform poorly, the Department will not require the removal of the MTDs installed in Virginia for testing purposes or otherwise installed during the testing period. However, localities have the discretion to apply conditions to the installation of BMPs within their jurisdictions.

2.3 -- General Use Designation (GUD)

The **General Use Designation** (**GUD**) confers a general acceptance for the stormwater MTD based on MTD performance of phosphorus removal and factors that influence the performance. Proponents seeking a **GUD** shall have field tested the MTD in at least two field sites. The testing shall conform to the requirements in this VTAP document for at least one field test site (see

Table 2.1), including that the test sites must be representative of urban stormwater runoff in Virginia (see Table 2.2).

MTDs with a **GUD** shall be listed as such on the Clearinghouse website and awarded a pollutant removal credit based on the test results. MTDs with a **GUD** from the Department may be used anywhere in Virginia, subject to approval by the jurisdiction operating the local Virginia Stormwater Management Program and conditions that the Department or the jurisdiction may impose. MTDs that receive a **GUD** have no expiration date.

If at a later date, it is discovered that a MTD with a **GUD** is not performing at the assigned pollutant removal credit, the evidence for lack of performance and other relevant information would be submitted to the Clearinghouse Committee for review and recommendation. The Director would make any final approvals/disapprovals. During this review process, the practice would be removed from the Clearinghouse website until the PR credit is changed, the design criteria are improved to achieve the listed performance, or the matter is otherwise resolved.

2.4 -- Applying for the Appropriate Use Designation

In deciding for which use designation to apply, the proponent needs to ask a fundamental question:

> **Does the MTD have field performance data, and do these data meet the VTAP requirements?**

To determine the answer to this question, the proponent of the MTD needs to be familiar with the information in this VTAP document.

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

- Proponents of MTDs with full-scale laboratory performance data for TP, TSS, or SSC and no, or limited, field testing data may submit a **PUD** application.
- Proponents of MTDs with field performance data that meet the following criteria may submit a **CUD** application:
  (a) The TP removal data were collected from at least one field site, and
  (b) The testing procedures conform to an established protocol, such as the VTAP, TARP (2003), TAPE (WSDOE 2008, 2011) or other protocol with phosphorus testing that is accepted by the Department.
- Proponents of MTDs with field performance data that meet the following criteria may submit a **GUD** application:
  (a) The TP removal data were collected from at least two field sites, and
  (b) The testing procedures conform to the VTAP for at least one field test site, including that the test sites must be representative of urban stormwater runoff in Virginia. The testing procedures are consistent with VTAP, TARP (2003), TAPE (WSDOE 2008, 2011), or other protocol with phosphorus testing that is accepted by the Department for the other field test site(s).

3 -- Assessment Process

The Virginia Stormwater BMP Clearinghouse shall maintain a list of approved MTDs on the Clearinghouse website to assist local jurisdictions in identifying stormwater technologies. MTDs undergoing testing to meet criteria of the **General Use Designation** (**GUD**) may be listed on the Clearinghouse website with either a **Pilot Use Designation** (**PUD**) or a **Conditional Use Designation** (**CUD;** refer to **Section 2 -- MTD Use Designations**).

3.1 -- Overview of Virginia Technology Assessment Protocol and Timeline

The assessment process for approving MTDs for the treatment of phosphorus in post-construction, stormwater runoff in Virginia is explained in the steps below and illustrated in Figure 3.1. Required deadlines are shown in bold-faced type. The other times listed are guidelines for the amount of time expected for a given step in the process. The Department's evaluator(s) will review completed applications in the order they were received, evaluate submittals as quickly as possible, and communicate with the proponent of the MTD if delays or problems arise.

Failure to submit progress reports or failure to demonstrate satisfactory progress during the testing period risks suspension or cancellation of the use designation and possible removal from the Clearinghouse website. A MTD with a suspended **PUD** or suspended **CUD** shall not be installed in Virginia during the suspension period. Suspensions granted because of a lack of progress shall be removed when the proponent demonstrates satisfactory progress in completing the required component. Furthermore, if undesirable trends become evident during the testing phase, the Department may call for the suspension of the approved **PUD** or **CUD**, in which case, the MTD may not be installed in Virginia until the problem is found and corrected. If the undesirable trends are serious enough, the Department may issue a cancellation, whereby the MTD shall be removed from the Clearinghouse website and shall not continue to be installed in Virginia. The proponent of a cancelled MTD shall resubmit an application after the issue(s) have been addressed in order to have the MTD re-evaluated.

The PUD or CUD shall expire after 24 months from the time the first QAPP is approved by the Department unless the Department grants an extension of the testing period. A MTD with an expired **PUD** or expired **CUD** shall be removed from the Clearinghouse website and shall not continue to be installed in Virginia. The proponent of an expired MTD shall submit a subsequent application (assumedly at a higher use designation) in order to have the MTD evaluated. In an effort to prevent the expiration of a **PUD** or **CUD**, the proponent of a MTD may submit a request to the Department for an extension of the testing period. In order for the proponent to gain additional testing time and continue to install the MTD in Virginia, the proponent must receive approval of an extension request from the Department's Stormwater Regulatory Program Manager or designee.

1. The assessment process in Virginia begins when the proponent submits a **PUD**, **CUD**, or **GUD** application to the Department.
2. Submitted applications shall be reviewed for completeness by the Department's evaluator(s). (within approximately 15 calendar days)

3. If the application is complete, the Department's evaluator(s) shall assess the application and recommend a use designation and a PR credit. (within about 60 calendar days)
4. **If recommended by Department's evaluator(s), the technical evaluation report (TER), submitted as part of the application, shall be included on the Clearinghouse website for public comment for 30 calendar days.**
5. The Department shall respond to the public comments and shall provide the responses to the Clearinghouse Committee. (within about 30 calendar days)
6. The Clearinghouse Committee shall review the application, recommendations made by Department's evaluator(s), public comments, and responses to the comments. The Clearinghouse Committee shall develop a use-designation recommendation and a PR credit recommendation. The Clearinghouse Committee shall notify the proponent and the Department of its recommendations. The Clearinghouse Committee meets quarterly and shall review applications in the order they were received by the committee. Depending on the number of applications to be reviewed, the submitted application shall be assessed at the earliest possible Clearinghouse Committee meeting.
7. The Director shall review all recommendations and determine an appropriate use designation (i.e., no use designation, provisional **PUD**, provisional **CUD**, or **GUD**) and a PR credit if applicable. (within approximately 45 calendar days)

MTDs approved at the **GUD** level shall be listed on the Clearinghouse website. If a MTD is not awarded any type of approval and the proponent desires to continue seeking approval, the proponent of the MTD shall need to reapply once the identified issues have been addressed. For MTDs with provisional approval at the **PUD** or **CUD** levels, the process continues as described below:

8. Proponents of MTDs with approvals at either the provisional **PUD** or provisional **CUD** level shall begin to provide quarterly status reports to the Department. Reporting time begins once granted the provisional approval. **Quarterly status reports are due to the Department for the preceding 3-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**.

   The proponent shall continue to submit quarterly progress reports to the Department until submission of the application for a higher use designation at the conclusion of the testing period.
9. A Department-approved QAPP is required for each field test site. The proponent's technical advisor must review and approve the QAPP prior to its submission to the Department.
10. The Department's evaluator(s) shall review each QAPP, and members of the Clearinghouse Committee shall have the opportunity to comment on the QAPP during this time. (within about 60 calendar days)
11. The Department's Stormwater Regulatory Program Manager or designee shall review all comments and recommendations received for each QAPP and shall either approve or disapprove each QAPP. If the QAPP is disapproved by the Department, the proponent shall modify and resubmit the plan in order to have it reviewed again. Once the Department officially assigns the MTD an official **PUD** or **CUD** designation and the QAPP is approved, the VWRRC will list the MTD on the Clearinghouse website. (within about 15 days) The Department will then allow the MTD to be installed in Virginia, the field performance testing to begin at the site associated with the QAPP, and the **24-month testing period** to begin.

12. The proponent shall conduct field testing according to the procedures outlined in the approved QAPP. The proponent shall notify the Department of all locations of the MTD installed in Virginia during the testing period. **If field testing is not completed with 24 months (or other time period specified by the Department), the proponent of the MTD shall submit to the Department a request for an extension of the testing period.** In order for the proponent to gain additional testing time and continue to install the MTD in Virginia, the proponent must receive approval of an extension request from the Department's Stormwater Regulatory Program Manager or designee.
13. At the end of the testing period, the proponent of a stormwater MTD may submit an application for a higher use designation to the Department.
14. Submitted applications shall be reviewed for completeness by the Department's evaluator(s). (within approximately 15 calendar days)
15. If the application is complete, the Department's evaluator(s) shall assess the application and recommend a use designation and a PR credit. (within about 60 calendar days)
16. **If recommended by the Department's evaluator(s), the TER, submitted as part of the application, shall be included on the Clearinghouse website for public comment for 30 calendar days.**
17. The Department shall respond to the public comments and shall provide the responses to the Clearinghouse Committee. (within about 30 calendar days)
18. The Clearinghouse Committee shall review the application, recommendations made by Department's evaluator(s), public comments, and responses to the public comments. The Clearinghouse Committee shall develop a use-designation recommendation and a PR credit recommendation. The Clearinghouse Committee shall notify the proponent and the Department of its recommendations. The Clearinghouse Committee meets quarterly and shall review applications in the order they were received. Depending on the number of applications to be reviewed, the submitted application shall be assessed at the earliest possible Clearinghouse Committee meeting.
19. Once reviewed by the Clearinghouse Committee, the Director shall review all recommendations and comments and make a decision. (within approximately 45 days) The Director may decide to issue a higher use designation (i.e., provisional **CUD** or **GUD**), revoke the current use designation, or grant an extension of the testing period for a specified time. MTDs approved at the **GUD** level shall be listed on the Clearinghouse website by the VWRRC. (within approximately 15 days of Department notification of the approval) MTDs granted a provisional **CUD** will need to follow the steps outlined above, beginning at step 8. If the current use designation is revoked, the proponent shall be notified of the Department's decision and reason for it. If the testing period is extended, the proponent shall follow the steps above, beginning at step 12, and using the testing time period specified by the Director.

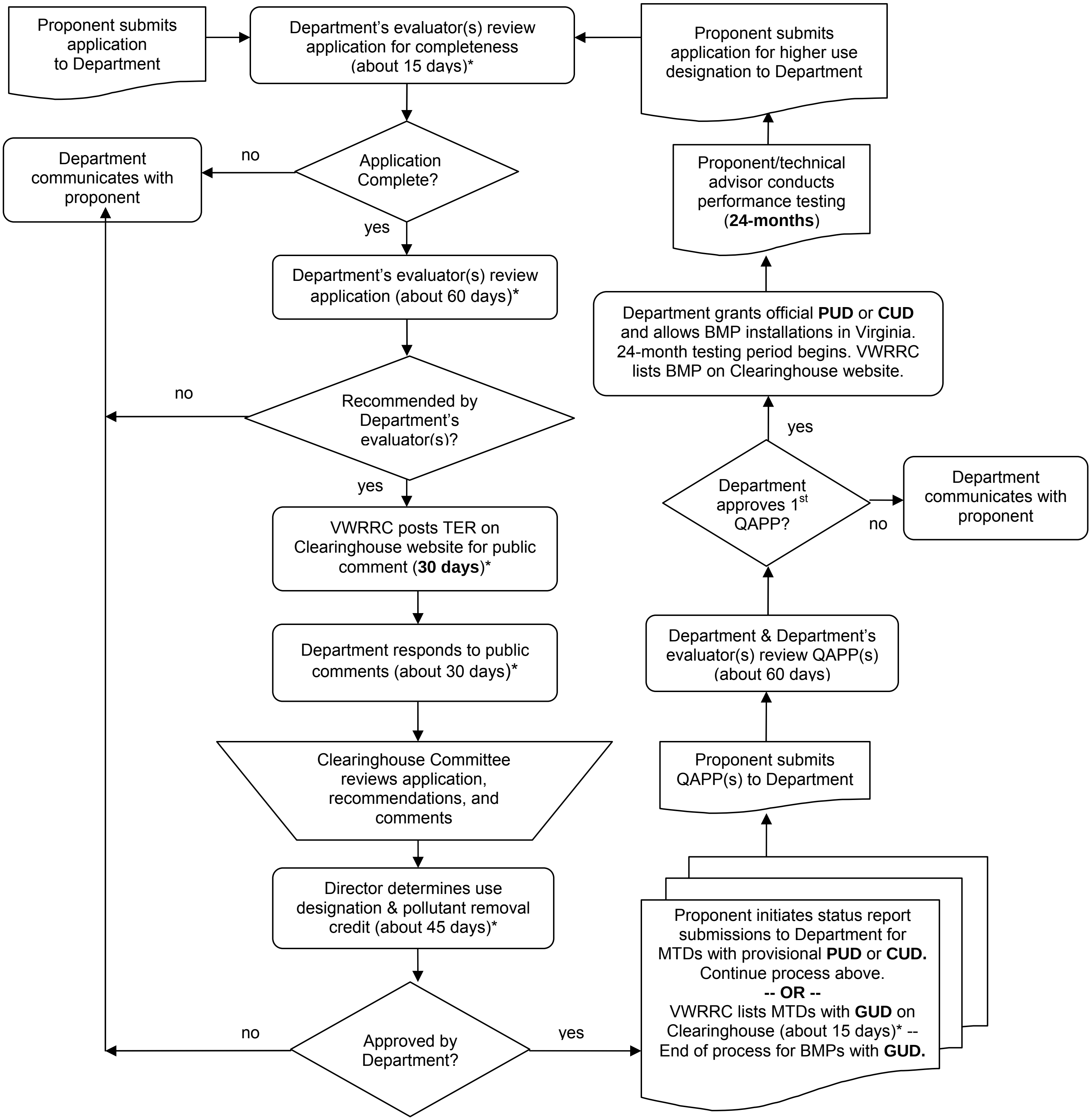

Figure 3.1. Flow chart illustrating the approval process in Virginia for stormwater manufactured treatment devices.

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

3.2 -- Requesting a Use Designation

Proponents seeking a use designation by the Department shall submit an application to the Department (see **Section 5 -- Application and Reporting**). The proponent shall submit an electronic version of the application, on a digital Compact Disc or as an e-mail attachment, to the Department at the application submission address listed on the Virginia Stormwater BMP Clearinghouse and follow the instructions on the application form for paying the appropriate application fee. For assistance, please contact the Department by using the contact information listed on the Virginia Stormwater BMP Clearinghouse.

3.3 -- Approval of a Quality Assurance Project Plan

Once provisional approval is granted for a specific use designation (i.e., **PUD** or **CUD**), ***a quality assurance project plan (QAPP) for each field test site shall be submitted to the Department for review by the Department's Stormwater Regulatory Program Manager or designee. At least one Department-approved QAPP is required for official approval at the PUD or CUD levels in Virginia. Furthermore, the proponent shall not install the BMP to be tested in Virginia until the QAPP is approved by the Department, unless the testing is being done on a MTD that had been installed in the past.*** Once the QAPP for the test site is approved by the Department, the 24-month testing period will begin.

The Department shall identify evaluator(s) to review and provide recommendations concerning approval of QAPPs, and members of the Clearinghouse Committee shall have the opportunity to comment on QAPPs. The Department's Stormwater Regulatory Program Manager or designee shall make the final decision concerning QAPP approval.

The Department recommends that the proponent not begin performance testing until after the QAPP is approved. Even when testing sites are located outside the state of Virginia, Department-approved QAPPs are required for those sites in order to use them to receive a use designation in Virginia. If the QAPP is NOT approved by the Department, the proponent shall modify and resubmit the plan in order for it to be reviewed again.

When a change in procedure is warranted for an approved QAPP, the author of the plan shall seek approval from the Department to use the amended QAPP. Proponents shall submit the updated QAPP to the Department along with a cover letter that explains what changes were made and why. The Department's Stormwater Regulatory Program Manager or designee shall approve or disapprove the amended QAPP. Once approved by the Department, the revised plan shall be sent to all the individuals cited in the QAPP distribution list for implementation. Changes in key personnel associated with the project do not need to be approved by the Department but shall be reported to the Department.

3.4 -- Granting and Appealing Use Designations

3.4.1 -- Granting a Use Designation

The Director grants a use designation and PR credit based on the information submitted, recommendations from the Department's evaluator(s) and the Clearinghouse Committee, comments received from the public and responses to those comments, and best professional judgment. The Director shall base decisions on the system performance and factors that influence the performance (e.g., sizing, maintenance).

The Department or local governments (4 VAC 50-60-65d) may place restrictions on the use of MTDs granted a **PUD**, **CUD**, or **GUD** (see **Section**. **1.6 -- Protocol Limitations, Release of Liability, and Disclosure**).

For approved MTDs, the proponent shall provide design specifications and operation/maintenance specifications for the MTD that are consistent with the accepted research findings. The proponent and the Department's evaluator(s) shall work in collaboration to develop information about the approved MTD for inclusion on the Clearinghouse website.

3.4.2 -- Appealing a Use Designation

Any owner aggrieved by an action taken by the Director without hearing may demand in writing an informal fact-finding proceeding pursuant to § 2.2-4019 of the *Code of Virginia*.

4 -- Field Monitoring and Data Evaluation

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. Estimating Pollutant Removal
10. Preparation of the Technical Evaluation Report (see **Section 6.4 -- Technical Evaluation Report [TER]**)

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

4.1 -- Monitoring Site Selection

The success of the field monitoring program will depend in large part on locating a suitable test site. The Department 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 (refer to Table 2.2). The Department recommends that proponents select test sites that incorporate characteristics consistent with the intended applications and geographical locations for the MTD and have 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 Department recommends that the sites be well-established with no on-going land development and/or disturbance activities. Consideration of the following factors is recommended:

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

- Ensure that the storm drainage system is sufficiently understood to allow a reliable delineation and description of the catchment area (e.g., geographic extent, topography, soils, land uses).

4.2 -- QAPP and Documentation

Once provisional approval is granted for a specific use designation (**PUD** or **CUD**), a quality assurance project plan (QAPP) *shall be submitted to the Department and approved by the Department for each field test site* (see **Section 3.1 -- Overview of Virginia Technology Assessment Protocol and Timeline** and **Section 3.3 -- Approval of a Quality Assurance Project Plan**). The Department recommends that the proponent of the MTD and the proponent's technical advisor develop QAPPs collaboratively, taking particular care to ensure that field and laboratory QAPP elements are well integrated (see **Section 1.4 -- Roles and Responsibilities**).

4.2.1 -- Preparation of a QAPP

The QAPP shall specify the procedures to be followed to ensure the validity of the test results and conclusions. A QAPP addresses the basic elements and shall 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 shall 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 shall 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 if applicable, and analytical laboratory that performs the sample analyses.
- Identify the proponent's technical advisor and/or third-party observer.
- Identify the roles and responsibilities of each study participant.
- 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 MTDs are proper.
- Provide a schedule documenting when the field-monitoring equipment is expected to be installed, the expected field testing start date, projected field sampling completion, and final project report submittal.

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 MTD 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 MTD (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.)
    - identify design maximum hydraulic loading rate (i.e., peak flow rate) using the calculation in Section 11.5.2.3 of Chapter 11 of the Virginia Stormwater Management Handbook and standard of 1-inch of rainfall;
    - make, model, and capacity of the MTD;
    - 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 MTD (specify the bypass flow set point). In the VTAP, bypass refers to flow that enters the MTD but is diverted prior to treatment. External diversions before the inflow is recorded are not considered to be bypasses in the VTAP, however the drainage area with the diverter shall be provided;
    - pretreatment system set-up and operational details, if required by site conditions or MTD 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) (The Department recommends that test objectives be clear, concise, quantitative, and unambiguous, such that standardized test methods and procedures can be applied and that the entire range of MTD performance capabilities be tested in order to demonstrate the full

potential of the MTD.) (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/qa_docs.html);
    - sampling equipment and procedures;
    - method of calibrating the flow metering system
    - 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 cross-contamination of samples.);
    - 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 cleaning and maintenance procedures.
- 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 accredited/certified under 1 VAC 30 Chapter 45 or 1 VAC 30 Chapter 46 is required to receive a GUD** (see **Section 4.5.8 -- Laboratory QA/QC Procedures**). Use equipment manufacturer's recommended instrument calibr**ation/certification procedures.**

In addition, the QAPP shall address the requirements stated in the other sections **of this document (particularly Section 4.3 -- Monitoring Program Design** and **Section 4.5 -- Sample Collection, Analysis, and Quality Control**).

Standardized test methods and procedures shall be used to collect stormwater MTD 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/qa_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).
- 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).

Department may allow flow-controlled field test sites. Flow-controlled field test sites use actual stormwater but control the flow through MTDs 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 shall include measures to estimate flow and mass flux in both the treated and bypass flows.

A QAPP is required for each test site for MTDs intended to be approved for use in Virginia, whether the test site is in Virginia or not.

The proponent shall submit an electronic version of the QAPP, on a digital Compact Disc or as an e-mail attachment, to the Department at the submission address listed on the Virginia Stormwater BMP Clearinghouse. For assistance, please contact the Department by using the contact information listed on the Virginia Stormwater BMP Clearinghouse.

4.2.2 -- 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 shall be developed for the test site(s), including confined space entry if applicable.

- **Work Permit for Confined Space**. If applicable, the field crew shall fill out a “permit” for each confined space entry with names and qualifications of the personnel involved and the procedure that was followed.

- **MTD Inspection-Maintenance Log**. Following the inspection and maintenance procedures outlined in the MTD’s Operation and Maintenance Manual, the field crew shall record the accumulation of sediment, oil, and trash in the MTD. The recorded data shall be used to establish the maintenance frequency of the MTD.

- **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.

4.3 -- Monitoring Program Design

The monitoring program shall be designed in accordance with the procedures described in the QAPP approved by the Department. The monitoring program shall reflect the intended applications of the MTD. Samples should be collected over a range of rainfall intensities encountered during the year.

In the event that changes in procedures are warranted, the QAPP shall be amended to document the changes, and the amendments submitted to the Department and approved by the Department prior to implementing the revised plan. For more information, see **Section 3.3 -- Approval of a Quality Assurance Project Plan.**

4.3.1 -- MTD Sizing Methodology for Test Sites

Proponents need to verify that the MTD can treat the runoff of 1-inch of rainfall. The proponent shall submit methods to select the size of the MTD in the test system based upon standard design criteria for the MTD, including but not limited to peak flow rate or water-quality treatment volume, drainage area, and predicted performance. The Department recommends that the facility sizing methodology reflect the design basis of the MTD and be sufficiently generalized for all sites. The Department also recommends that the applicant provide specific supporting calculations 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 MTD.

4.3.2 -- Monitoring and Sampling Parameters

The following subsections provide the protocol for data collection. It is largely based on sections selected from the TAPE (WSDOE 2008, 2011) and TARP (TARP 2003, NJDEP 2009) programs. Although there are different approaches for collecting performance data, the following protocol is considered by the Department to be necessary for obtaining scientifically valid data, particularly for field demonstrations.

4.3.2.1 -- Qualifying Storm Event Parameters

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

- More than 0.1-inch of total rainfall. If a storm with more than 0.1-inch of rainfall has measurable runoff at the inflow of the MTD but produces no discharge, report the occurrence of the storm and record that the MTD effectively treated all runoff, but the storm may not count towards the minimum number of storms required for testing, subject to consideration by the Department's technical evaluator(s) (see **Section 4.3.2.4 -- Minimum Number of Events Required to be Sampled**).

- Minimum inter-event period of 6 hours.
- 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 feasible shall be taken for all constituents on which PR credits are to be computed.
- A minimum of 10 aliquots (i.e., 10 influent and 10 effluent aliquots) shall be collected per storm event. Exception: for short duration storms, those less than 1-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. 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 4.3.2.5 -- Sampling Methodology**. This larger number of aliquots, if planned appropriately, does not increase the sampling burden of the applicant.

4.3.2.2 -- Rainfall Monitoring

Rainfall shall be recorded during each and every storm event. Measurement sensitivity shall be no greater than 0.01 inch, and a maximum intensity measurement capability of no less than 4 in./hr. 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 the Department. 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 shall be established with the recorded rainfall at the monitoring site, and used to compute the local (monitoring site) rainfall.

4.3.2.3 -- Flow Monitoring

To the extent feasible, all flow (inflow, outflow and bypass) shall be accounted for and monitored. Inflow to and outflow from the test unit shall be measured and recorded on a continuous basis over the duration of each sampling event. The appropriate flow measurement method depends on the nature of the test site and the conveyance system. For those systems with bypasses, flows shall be measured at the bypass as well as at the inlet and outlet. Flow measurement procedures shall be fully described in the QAPP and evidence of calibration provided. The flow data recording interval shall provide adequate definition of the inflow and outflow hydrograph, but in no case shall flow be logged at an interval greater than 5 minutes.

4.3.2.4 -- Minimum Number of Events Required to be Sampled

Statistical methods may be used to develop an estimate of the required sample size. There are a variety of methods for calculating sample size for various confidence levels (e.g., refer to Burton and Pitt 2002, Sample et al. 2012, Bootstrapping calculation tool at Washington Stormwater Center [http://www.wastormwatercenter.org/tape-program]) However, a critical assumption of the statistical method is that events are independent, i.e., the performance of the MTD 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.

For the purposes of MTD testing under this guidance, the minimum number of events required to be sampled is set at 18 qualifying storms with measurable inflow and outflow, provided the confidence level exceeds 50% and approval is granted by the Department. Otherwise, 24 qualifying storms with measurable inflow and outflow is the minimum. A basis for this relationship is developed in more detail in **Appendix A -- Number of Tests**.

The Department recommends that proponents establish a goal of sampling a continuous sequence of qualifying events, or as close as possible to that goal. 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. At a minimum, five sets of qualifying back-to-back storms (five sets of two qualifying storm events in sequence for a total of 10 storms) shall be sampled.

At least one sampled rainfall event shall be greater than 1 inch, and at least three sampled events shall be greater than 0.5 inches. In addition, the Department recommends that, when feasible, a proponent monitor a minimum of two events where peak flow rate exceeds 75% of the design capacity. The sampling and performance results for all sampled qualifying storms shall be reported and included in all performance and maintenance interval computations.

4.3.2.5 -- Sampling Methodology

Sampling protocols shall 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 MTD performance measurements.

- **Grab samples** are discrete, individual samples taken within a short period of time (usually less than 15 minutes). Grab samples may be used for certain constituents, in accordance with accepted standard sampling protocols, but not 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 4.1. 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:

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

$$\text{where } \Delta V_i = \text{incremental runoff volume, } L^3$$

$$C_i = \text{constituent concentration } m/L^3$$

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 is expected, in theory, to 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.

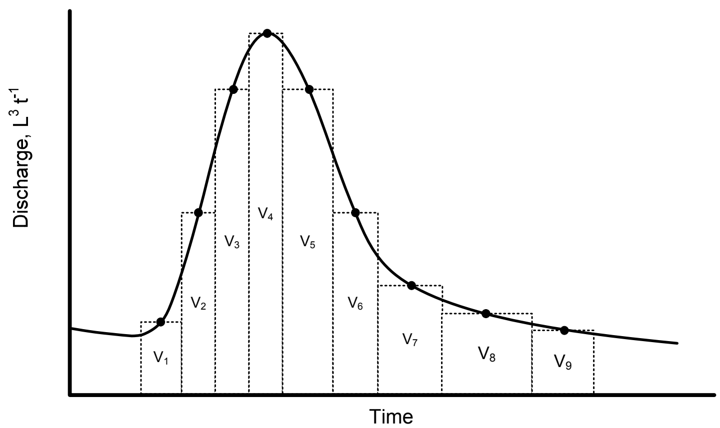

Figure 4.1. Equal volume, variable time, flow-weighted composite (Graphic courtesy of T. Grizzard)

- **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 are recommended. 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 ($V_E t_V$)

  Figure 4.1 may again be used to illustrate the $V_V t_V$ compositing approach. Note that there are 9 samples and 9 volumes in Figure 4.1. 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 x 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 shall 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 4.2. 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 4.2, 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.

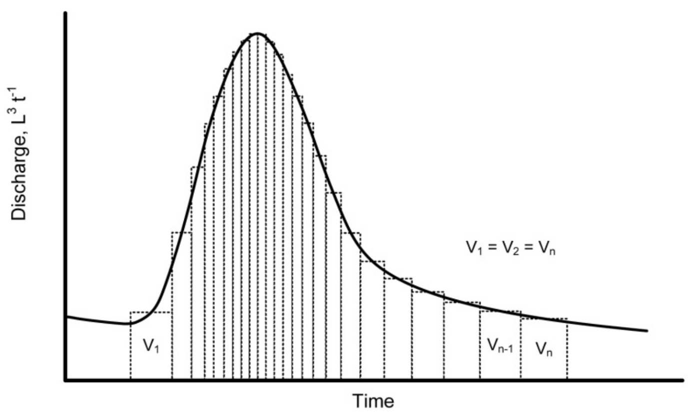

Figure 4.2. Equal volume, variable time, flow-weighted composite (Graphic courtesy of T. Grizzard)

4.3.2.6 -- Maintenance Monitoring

When 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 MTD 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 shall 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 shall agree to conduct long-term periodic monitoring to show how performance varies over time and shall monitor the qualifying events immediately before and after maintenance***.

4.3.3 -- Phosphorus Monitoring Overview

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-µm membrane filter (TSP passes through the filter whereas PP does not).

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.

4.4 -- Monitoring System Design and Installation

Use the information in this section when designing the monitoring system for the collection of performance and maintenance data.

4.4.1 -- Monitoring System Design

The physical layout of the monitoring system may have direct impacts on MTD pollutant removal. 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 MTD effectiveness. 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 MTD shall be considered when designing the monitoring system.

Flow monitoring stations have the following requirements:

- For stations where flow is to be measured in open channels, locate the flow measurement facilities 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 MTDs most often include a properly calibrated weir or flume. Select the control 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 shall be made for adequate demonstration of precision and accuracy.

- Where possible, locate stations 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. Avoid steep channel slopes, changes in pipe diameter, conduit junctions, and areas of irregular channel shape (e.g., breaks, repairs, roots, debris, etc.).

- Locate stations established in pipes, culverts, or tunnels in such a way to avoid surcharging (pressure flow) over the normal range of precipitation.

- Locate sampling stations for the MTD as close as feasibly possible to the MTD inlet and outlet in order to avoid potential sources of pollutants that bias the study results (and the derived MTD pollutant removal data).

- Locate influent sampling stations 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 used and the access point is a manhole, the water surface elevation shall not be excessively deep (i.e., it is recommended to 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 positioning is necessary to avoid unacceptable intake velocity reductions due to increased pump suction lift.

  When locating the sampler intake, consider the expected velocity profile in the type of channel being used; see Figure 4.3 from Chow (1959).

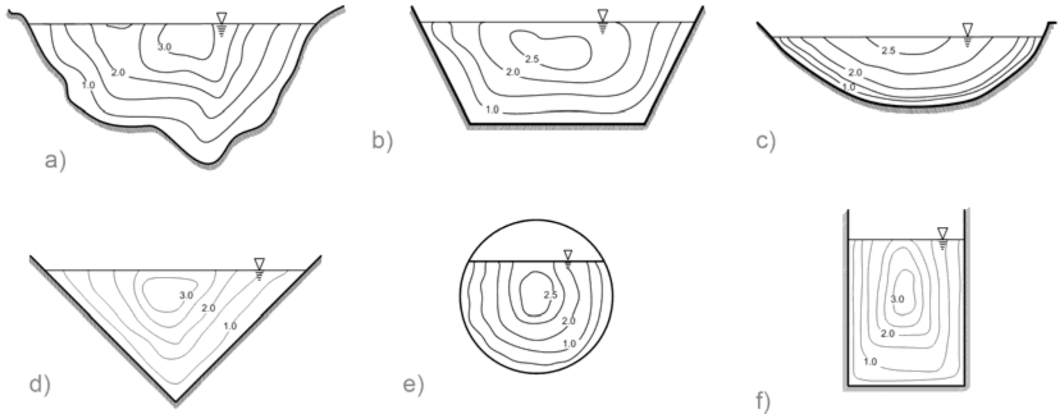

Figure 4.3. Typical velocity distributions (ft./sec.) for a) natural channel, b) trapezoidal channel, c) parabolic channel, d) triangular channel, e) pipe, f) rectangular channel. Modified from Chow (1959) (Graphic courtesy of T. Grizzard)

- In addition, evidence shall be provided to insure that carry-over of compounds between samples (e.g., adherence to the sampling equipment surfaces) is not taking place.

- For systems that bypass runoff, the influent sampling station shall be directly upstream of the system and before the flow is split between the treatment system and the bypass. The outflow sampling location shall be located directly downstream of the treated flow (i.e., the MTD) and after the effluent joins the bypass flow. If the treated effluent flow does not join the bypass, the bypass shall be monitored after the split.

The following recommendations apply to all monitoring stations:

- Avoid monitoring sites in locations that may be affected by backwater and tidal action because such conditions may adversely impact the reliable measurement of flow.

- Where feasible, take TSS measurements from multiple flow-weighted cross-sectional samples at various flows and compare to the point intake TSS value to insure that intake location is not creating bias in sample results.

- Locate stations where field personnel may safely access the equipment for construction, maintenance, and sample retrieval, e.g., 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, configure the monitoring system such that confined space entry (for equipment installation, routine servicing, and operation) can be performed safely and in compliance with applicable regulations.

- Locate stations where access and security are good, and vandalism of sampling equipment is unlikely.

- Located stations where the channel or storm drain is soundly constructed.

- Establish groundwater monitoring wells if contamination of groundwater is suspected. Establish groundwater flow, direction and elevation as well as soil types before choosing monitoring stations. Locate monitoring stations sufficiently down gradient from the MTD in order to intercept infiltrated water from the MTD.

The Department recommends that the proponent visit each candidate site during or after a storm to observe the discharge. A wet-weather visit can provide valuable information regarding logistical constraints that would not be readily apparent during dry weather.

4.4.2 -- 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**: When feasible, locate a rainfall monitoring station at or within 200 feet 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 Department recommends that the rain gauge interface with a data acquisition system that uses the same electronic time base as flow measurements.

- **Inlet and Outlet Flow Monitoring**: When feasible, locate flow monitoring equipment at both the MTD inlet and outlet. Use of both primary and secondary flow measurement devices are recommended whenever feasible. 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. The Department recommends that flow monitoring equipment have the capability to measure discharge from near zero to full pipe (or cross-section) conditions. Carefully chose sampling/monitoring sites to be consistent with the requirements of the primary devices selected. Generally, this positioning 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. Evaluate sites carefully and decide to include them only after it has been demonstrated that the impacts on the quality of discharge measurements have been satisfactorily addressed.

- **Stage and Bypass Flow Monitoring**: For MTDs that are predominately filtration devices, stage-discharge shall be measured in the unit tested. The proponent shall assess the potential for periodic clogging of the filter media and develop recommendations for when maintenance is needed. In addition, bypasses shall be assessed and reported.

- **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 are preferred unless it is demonstrated that alternate methods are superior or where automatic sampling is infeasible. Locate automatic samplers at the MTD inlet and outlet, and configure them to be activated by the data acquisition/control system in accordance with the sampling scheme (discrete, composite) adopted for the study. Where feasible, locate sampler intakes in sampling chambers designed to provide well-mixed conditions. Otherwise mount sampler intakes 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) shall be selected to ensure the desired representativeness of the sample. The sampler intake tubing material shall be selected to be consistent with the constituents to be analyzed. Initiate sample aliquot collection by signals from the data acquisition/control system.

- **In Situ Monitoring**: Attachment of in situ monitoring equipment such as temperature probes and pH probes to internal surfaces where conditions are well-mixed is preferred.

- **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, it is recommended that the system 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 Department recommends that the data acquisition system have a primary power source, a backup power source, and a means of being queried through an internal cellular or land-line telephone modem.

- **Weatherproof Shelter**: The Department recommends the use of a weatherproof shelter or trailer to house the data acquisition system and automatic samplers and recommends that the shelter be sized with adequate clearance to easily remove samples, and to permit maintenance activities during storm events without exposing equipment to the elements.

Calibrate and maintain all monitoring equipment in accordance with the recommendations of the equipment providers.

4.5 -- Sample Collection, Analysis, and Quality Control

The following subsections detail the protocol for sample collection, analysis, and quality control.

4.5.1 -- Stormwater Sampling

All stormwater samples shall be collected and analyzed in a manner that supports the construction of a mass-based assessment of MTD performance. Therefore, when feasible, all runoff (i.e., untreated runoff, treated runoff, bypassed flows, etc.) is to be monitored. While the analytical work is generally undertaken at a laboratory remote from the sampling site(s), it is recommended that care be taken that the sampling protocols in use at the site are consistent with the analyses contemplated.

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

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

The Department recommends that other parameters that influence phosphorus speciation, such as pH, alkalinity, temperature, turbidity, and redox potential be included in the analytical program, and may be monitored in situ or through sample collection, as appropriate.

PP may be calculated by subtracting TSP from TP. The PP load in stormwater is related to the PSD. Generally, the finer fraction of suspended sediment contains the highest concentration of PP, which suggests that MTDs 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 MTD 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 MTD 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 the amount of MTD sediment removal (Geosyntec Consultants and Wright Water Engineers, Inc. 2009) and, by extension, PP load reduction.

4.5.2 -- Accumulated Sediment Sampling

Where appropriate, it is recommended that the sediment accumulation rate in the MTD 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
- specific gravity.

Use several grab samples (at least four) collected from various locations within the treatment system to create a composite sample of the sediment. This method is intended to collect a representative sample of the total sediment volume in the treatment system. For QA/QC purposes, collect a field duplicate sample (see **Section 4.5.7 -- Field QA/QC Procedures**). Keep the sediment sample at 4^{o}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.

4.5.3 -- 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 shall 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 shall be included in the QAPP.

Provide preservation during sample collection, as well as during transport. Samples shall 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 shall be cooled to maintain low temperatures throughout the sample collection period.

Samples shall 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 shall 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 shall 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 shall 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 shall 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.

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.

4.5.4 -- Analytical Methods

Proposed analytical methods shall be included in the QAPP.

4.5.4.1 -- Standardized Test Methods

Standardized test methods shall be used to collect stormwater MTD data. Methods often used for analyses of samples from aquatic systems include:

- *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
- American Society for Testing and Materials D5612-94(2008) (ASTM 2008).

Other nationally recognized organizations, such as the 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.

4.5.4.2 -- Analysis of Phosphorus

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-µm 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.

4.5.4.3 -- Analysis of Particle-Size Distributions

Due to the potential differences in precision among analytical procedures, it is recommended that the same analytical apparatus and procedures be employed throughout the test program. PSDs shall be determined through an appropriate method or combination of methods:

- Sieve Analysis
- Coulter Counter
- Hydrometer
- Laser Diffraction

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

4.5.5 -- 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. More detailed information on assessing quality control is provided in the following sections: **4.5.6 -- Monitoring Equipment QA/QC Procedures**; **4.5.7 -- Field QA/QC Procedures**; and **4.5.8 -- Laboratory QA/QC Procedures.**

The QC plan shall include the following:

- QC checks that shall be followed for all project activities and the frequency each shall occur.
- Control limits for each QC activity and the actions that shall 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, materials, frequency, criteria for acceptable method blanks and 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 shall constitute no less than 10% of the samples being analyzed, with at least one of each QC procedure specified per sample batch.

4.5.6 -- Monitoring Equipment QA/QC Procedures

Quality assurance (QA) describes a process meant to prevent problems, such as the use of standardized methods, and QC is a product-based approach used to detect problems that occur. QA and QC are largely interdependent and thus frequently described together.

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

4.5.6.1 -- Instrument/Equipment Calibration and Frequency

- **Automated Samplers**. Automated samplers shall 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 shall be calibrated using methods such as tracer dilution studies. velocity-area rating studies, or bucket rating. The Department recommends that the proponent repeat such studies 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 shall similarly be calibrated and verified in the field. Establish a stable datum for stage measurements at the time the station is constructed and periodically refer to it for subsequent calibrations and verifications. Most devices have well-developed procedures from the equipment supplier, and it is recommended to carefully follow these procedures.

- **Rain Gages**. The Department recommends that the proponent calibrate rain gages at the time of installation and periodically inspect/test them throughout the study to insure that operating characteristics have not changed. It is recommended that tipping bucket rain gages be located where they are not subject to the effects of wind eddy currents and turbulence. In general, obstructions (e.g., buildings, trees, etc.), may be no closer to the rain gage barrel than four 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 shall be carefully leveled and periodically tested to insure that indicated rainfall is consistent with the depth of rain applied to the gage.

4.5.6.2 -- Sampling Equipment Maintenance

Sampling equipment (sampler head and suction tubing) shall be cleaned and/or maintained 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 polluted runoff.

4.5.6.3 -- 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.

4.5.7 -- Field QA/QC Procedures

Field QA/QC procedures shall 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, field quality control shall include: field blanks, field duplicate samples, field sample volumes, recordkeeping, and chain of custody.

4.5.7.1 -- 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. The Department recommends that the collection and analysis of field blanks 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 it is recommended that the other components of the sampling process 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 are used to verify the adequacy of the cleaning and/or maintenance 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 pollutant 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 cleaning the equipment and after at least one storm event has been sampled. The field-blank sample volume is to be representative of the volume of stormwater collected during a typical sampling event.

Analyze field blanks as regular samples with all other appropriate quality control activities performed. It is recommended that the equipment-rinsate blanks 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 shall be taken (e.g., modifying equipment cleaning procedures, replacing suction tubing, etc.).

4.5.7.2 -- 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 are collected by filling two grab sample bottles at the same location. Field duplicate samples shall 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.

4.5.7.3 -- 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 shall be included in the QAPP.

4.5.7.4 -- Recordkeeping

Field logbooks shall 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 shall be made (e.g., sample integrity, test site alterations, maintenance activities, and improperly functioning equipment). At a minimum, the field notebook shall 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 shall 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 shall be provided in the QAPP.

4.5.7.5 -- Chain of Custody

The Department recommends that all sample custody and transfer procedures shall 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. The Department recommends the use of pre-formatted chain-of-custody forms to document the transfer of samples to the laboratory and the analysis to be conducted on each bottle. A sample chain of custody form shall be provided along with the QAPP.

4.5.8 -- Laboratory QA/QC Procedures

QA/QC procedures and standard operating procedures shall be documented in the laboratory quality manual, referenced in the QAPP, and made available for inspection if requested by the Department or its evaluator(s). Project requirements for laboratory QA/QC systems documented in the QAPP shall include, but are 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. The Department recommends that policies of corrective action, management audit, data integrity and ethics be outlined in the laboratory quality manual.

Laboratories accredited/certified under the Virginia Environmental Laboratory Accreditation Program (VELAP) shall perform the analytical work for applicable constituents (e.g., measuring TP and TSS concentrations) in order to receive a **GUD.** The Department recommends VELAP accreditation/certification for laboratories used by proponents seeking a **PUD** or **CUD**. Analyses that do not have a VELAP procedure do not need to be performed by a VELAP accredited and/or certified laboratory. However, laboratory procedures for the analysis of constituents that do not have VELAP certified/accredited procedures shall be reviewed on a case-by-case basis by the Department's evaluator(s) and the Department as part of the QAPP review/approval process. The Department recommends that the laboratory be a third-party independent lab, however, the proponent may use its own analytical laboratory provided all analyses are performed under the direct supervision of a third-party observer.

Virginia regulations (1 VAC 30 Chapter 45 or 1 VAC 30 Chapter 46 in the Virginia Administrative Code) establish VELAP to meet Section 2.2-1105 of the *Code of Virginia*, which calls for "a program to certify environmental laboratories that perform tests, analyses, measurements or monitoring required pursuant to the Commonwealth's air, waste and water laws and regulations." Therefore, VELAP accreditation/certification is needed for laboratories analyzing test data to assign PR credits for MTDs that could then be used to meet Virginia Pollutant Discharge Elimination System (VPDES), TMDL and other regulatory water quality requirements.

Additionally, 1 VAC 30-46-70 sets out the process that laboratories accredited by the National Environmental Laboratory Accreditation Program (NELAP) shall use to receive accreditation/certification in Virginia. Of particular interest, "NELAP-accredited environmental laboratories shall submit an application to DGS-DCLS [Department of General Services-Division of Consolidated Laboratory Services] no later than 180 calendar days prior to initiating the provision of environmental laboratory services in Virginia." For more detailed information on laboratory QC, consult VELAP at the Virginia Division of Consolidated Laboratory Services (http://www.dgs.virginia.gov/).

4.5.9 -- 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 MTD effectiveness monitoring, individual measurement results are combined into data sets for statistical evaluation. The MQOs for accuracy, precision, bias, and required reporting limits shall be presented in the QAPP. Reporting limits shall be provided in the QAPP. In some cases, a laboratory may need to reduce laboratory contamination sources to meet the reporting limits. Report any concentration that is less than the reporting limit as being one-half the reporting limit. If both input and output values are below the detection limit, note the storm in the report, but exclude the results from the statistical evaluation.

The following paragraphs define the DQIs and specify the methods used to evaluate them. Additional detail on the use of these methods to evaluate the precision, accuracy, and completeness of data is provided in **Section 4.5.5.2 -- Field QA/QC Procedures** and **Section 4.5.5.3 -- 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.

4.6 -- Data Verification, Validation, and Certification

Guidance concerning the data verification and validation processes is 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).

4.6.1 -- 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. Submit these documents to the data validator.

Verified data have been carefully reviewed. Any changes in the data from that originally reported shall 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. Identify deficient data, and document corrective actions. When data are not available to perform verification, state that the data could not be verified in the data verification records. Normally, data verification records include checklists, handwritten notes, data tables (electronic and/or hard copies), definitions, and supporting documentation for any laboratory qualifiers assigned. 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."

4.6.2 -- 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 and shall be performed by person(s) independent of the activity which is being validated. Validated data is expected to 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 shall be reflected in the validated data. Data that change as the result of validation shall be re-verified.

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 to consider 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 shall be qualified.

The data validation process results 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. It is recommended that the report 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 Department recommends that the report be written in easy to read “lay language,” as much as is feasible, because it is likely to be read by decision makers that do not have the same level of technical understanding that is typically shared by the researchers and technical advisors. The Department further recommends that the proponent include the following items in the data validation report:

- 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 shall 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, the Department and/or its evaluator(s) may ask the validator for clarifications and additional information at any time during the evaluation process.

4.7 -- 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. The Department recommends that data reports be reviewed for completeness as soon as they are received from the laboratory. Check reports 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) shall be performed prior to final data reporting or data analysis.

4.8 -- 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 follows 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 shall 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 MTD, and be able to assess and predict how mass moves through the MTD during each event. Both statistical and mechanistic approaches are necessary to fully characterize performance and reliability of the MTD.

4.9 -- Methods for Estimating Pollutant Removal

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 (see **Appendix C -- Pollutant Removal Calculation Methods**).

- **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 shall be calculated.

- **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. For example, 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 4.4, which is an example for suspended sediment reported by Geosyntec Consultants and Wright Water Engineers, Inc. (2009).

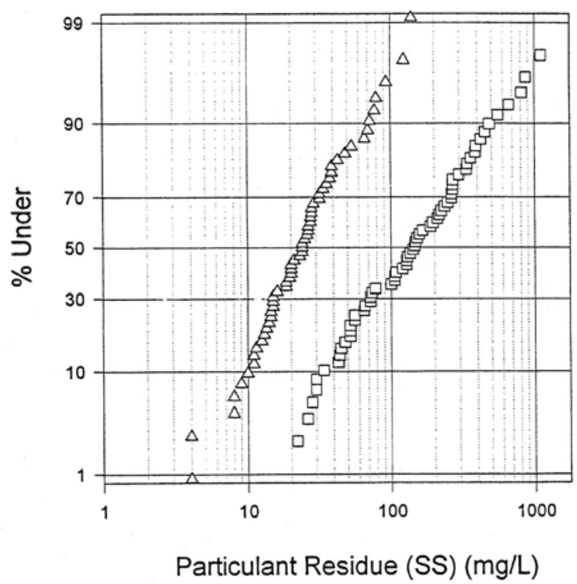

Figure 4.4. Illustration of effluent probability method for assessing pollutant removal of stormwater manufactured treatment devices

5 -- Application and Reporting

Complete all required components of the application before submitting it to the Department. In addition to providing the information requested in this document, the Department, the Department's evaluator(s), and/or the Clearinghouse Committee may request additional information on a case-by-case basis.

At a minimum, an application *shall* include:

- Completed Use-Designation Application Form
- Technical Evaluation Report
- Certification Statement

Submit an electronic version of the application, as a digital Compact Disc or e-mail attachment, to the Department at the application submission address listed on the Virginia Stormwater BMP Clearinghouse, and follow the instructions on the application form for paying the appropriate application fee. For assistance, please contact the Department by using the contact information listed on the Virginia Stormwater BMP Clearinghouse.

5.1 -- Use-Designation Application Form

Complete the use-designation application form available from the Department. Develop a title for the technology assessment project and use this title in all submittals associated with the project (e.g., QAPP, Status Reports, and Technical Evaluation Report).

- Be sure to check the desired designation level for which the MTD is to be evaluated: **Pilot Use Designation**, **Conditional Use Designation**, or **General Use Designation** (see **Section 2 -- MTD Use Designations**).
- If either the **PUD** or the **CUD** has been approved previously by the Department or approval has been granted in another state, indicate that this designation has been achieved and include the requested information.

5.2 -- Technical Evaluation Report (TER)

The Technical Evaluation Report (TER) is to be submitted to the Department as part of the application for MTDs seeking a **PUD**, **CUD**, or **GUD** in Virginia. The TER is to be written once performance testing is complete and the resulting data have been validated and analyzed.

If the MTD is recommended by the Department's evaluator(s), the TER shall be included on the Clearinghouse website for public review and comment. Thus, it is recommended that this component of the application be completed with the understanding that the information will be included on the Clearinghouse website for review purposes. Proprietary information that is not to be made public shall NOT be included in the TER but instead shall be submitted separately to the Department along with a completed confidentiality and non-disclosure agreement (see **Section 1.6 -- Protocol Limitations, Release of Liability, and Disclosure**).

5.2.1 -- TER -- Title Page

- Include: "Virginia Stormwater MTD Technology Evaluation Report."
- List the title of the project. Give the same title as that used on the use-designation application form (The form is available from the Virginia Stormwater BMP Clearinghouse website.).
- Provide the month and year of report submittal.
- List the name of the manufacturer.
- Include the contact information, including e-mail addresses, of key contacts where questions and correspondences may be addressed.

5.2.2 -- TER -- Executive Summary

The Department recommends that the proponent write the executive summary to include the following items:

- MTD name, function, and category (e.g., hydrodynamic separator, filter, etc.).
- Desired use designation for which the MTD is to be evaluated – (1) **Pilot Use Designation**, (2) **Conditional Use Designation**, or (3) **General Use Designation**.
- If either the **PUD** or the **CUD** has been approved previously by the Department, the applicant shall indicate that this designation has been achieved, along with the date of approval.
- If approval has been previously issued by another state, include the name of the granting agency, the level of approval, the protocol version under which performance testing occurred (if applicable), date of award, and the link to the Web page where the award is listed (if applicable).
- A brief performance claim that identifies the MTD's intended use and predicts the MTD's capabilities to remove phosphorus and/or reduce 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, stormwater conditions are not found in Virginia (see Table 2.2) and provide an opinion of how relevant these differences may be for consideration of a Virginia approval.
- If criteria in the VTAP have not been addressed, provide an opinion of how relevant such omission(s) may be for consideration of a Virginia approval.

5.2.3 -- TER -- Performance Claim

The Department will use the performance claim to evaluate the use designation. The Department recommends that performance claims be objective, quantifiable, replicable, and defensible. Wherever possible, include information about anticipated performance in relation to design, site conditions, storms and/or climate. Avoid claims that are overstated, as they might not be achievable and may result in rejection of the TER.

The Department recommends the proponent write the performance claim to include the following descriptions:

- Removal of TP and sediment in stormwater runoff and what those reductions are based upon (e.g., reduction of the event mean concentration [EMC] through the MTD's treatment processes [see **Appendix C -- Pollutant Removal Calculation Methods**], reduction of runoff volume, a combination of both, etc.).

- The conditions under which the reductions were achieved; e.g., the specific influent and effluent concentrations of phosphorus in tests (mean/median/range), the particle-size distribution of sediments in tests (specify D_{50}), the flow volumes treated versus volumes that bypassed the MTD treatment, etc.
- Application limitations of MTD if known to exist.
- The basis for sizing the MTD (e.g., hydraulic loading at a specific head, concentration of influent, etc.).

5.2.4 -- TER -- Technology Description

Design specifications for MTDs approved in Virginia at the **GUD** level shall be included on the Clearinghouse website. Thus, this section of the TER shall be completed and organized so that the information can be directly lifted from the application for inclusion on the Clearinghouse website. The Department recommends that this section of the TER contain information that addresses as many of the elements described below as applicable. At a minimum, all topic headings shall be addressed:

1. Description of Practice;
2. Performance Criteria;
3. Site Installation Requirements and Impacts;
4. Design and Sizing;
5. Material Specifications;
6. Construction Sequence and Inspection;
7. Operation and Maintenance;
8. System Longevity; and
9. References.

The Department recommends the use of the design specifications information for post-construction, non-proprietary BMPs listed on the Clearinghouse website as examples for the types of information to provide and the format to use in presenting the information (www.vwrrc.vt.edu/swc).

5.2.4.1 -- TER -- Description: Description of Practice

Begin the description with the name of the MTD and a photograph of it. Include the purpose of the MTD and cite the specific applications of the MTD. Provide detailed descriptions to ensure the reader can understand completely how the MTD works:

- Summarize the underlying scientific and engineering principles for the MTD. Describe the physical, chemical, and/or biological treatment processes.
- Describe significant modifications and technical advancements in the MTD design.
- Include details on relevant treatment mechanisms, such as those in Table 5.1.

Table 5.1. Measurements for various treatment mechanisms for manufactured treatment devices.

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.

5.2.4.2 -- TER -- Description: Performance Criteria

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

5.2.4.3 -- TER -- Description: Site Installation Requirements and Impacts

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

- **Siting location** – Contributing drainage area (including the effects of any diversions), upstream controls (non-structural and structural), available space needed, soil characteristics, hydraulic grade requirements, hydraulic capacity, minimum depth needed from water table, pretreatment requirements, etc.

- **Land use** – Provide the applications that the manufacturer recommends for the MTD (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 MTD within karst terrain; steep terrain; flat terrain; tidal areas; sites with shallow groundwater tables; cold climates; types of soil; linear highway sites; and proximity to wells, septic systems and buildings, etc. Also include limitations associated with the MTD's weight and buoyancy, transportability, durability, energy requirements, consumable materials, etc. Describe whether the following safety considerations favor or limit the MTD's use: facility depth limits for access and safety and hazardous materials spill risk. Describe how the limitation factors affect the MTD.

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

5.2.4.4 -- TER -- Description: 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. Follow the table format used in the design specifications information for post-construction, non-proprietary BMPs listed on the Clearinghouse website.

Include the following information as applicable:

- Design description and standard drawings (photographs may also be useful):
  - Schematic of the technology;
  - Diagram of the process and functions of the MTD;
  - Description of MTD's potential configurations;
  - Description of each treatment system component (engineering plans/diagrams of functional components, dimensions, description of each component's capacity, media or soil head-loss curves, etc.).
- Detailed description of the overall sizing methodology:
  - hydraulics (maximum treatment flow rate, bypass flow, hydraulic grade line, scour velocities, etc.);
  - 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; include sizing chart);
  - Soil infiltration rate testing, specific media surface loading rate and specifications, etc.
- Siting and design specifications to achieve stated performance, include (but not limited to):
  - If applicable: TP, SRP, PP, and sediment;
  - Optional: total nitrogen (TN), dissolved inorganic nitrogen, total Kjeldahl nitrogen (TKN), total ammonia-N, nitrate-N, nitrite-N, other pollutants such as metals or polycyclic aromatic hydrocarbons (PAHs);
  - identify pollutants that may be increased;
  - Stormwater constituent limitations (pollutants and other constituents), including fouling factors;
  - Range of operating conditions for the MTD, including minimal, maximal, and optimal influent conditions to achieve the performance goals and standards, and for reliability of the MTD, including modifications as needed to accommodate Type III (coastal) rainfall conditions;

- Pollutant removal at water quality design treatment flow rate at the water quality storm event (1-inch in 24 hours) and for representative stormwater characteristics;
- Design residence time, vertical/horizontal velocities, surface overflow rate, and other parameters relevant to the process, if applicable;
- Description of bypasses and/or diversions processes if applicable; and
- Description of pretreatment and preconditioning of stormwater if appropriate to achieve stated performance of the MTD

5.2.4.5 -- TER -- Description: 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.

5.2.4.6 -- TER -- Description: Construction Sequence and Inspection

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

Describe the following:

- The role the manufacturer/vendor takes in design and construction.
- MTD 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 MTD.
- Methods for diagnosing and correcting potential problems; identify who is responsible to diagnose and correct problems.
- Impacts to the MTD's effectiveness if problems are not corrected.

5.2.4.7 -- TER -- Description: Operation and Maintenance

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

- Date the manufacturer went into business. If applicant goes out of business or MTD model changes, describe how and where the facility owner will find needed parts, materials, and service.
- Whether the MTD 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.
- How operations and maintenance are performed. Personnel and equipment needs to operate and maintain the MTD. 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 or other safety issues.
- 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: number of inspection/maintenance visits expected annually, equipment rental and mobilization, solids/spent media disposal, etc.

5.2.4.8 -- TER -- Description: System Longevity

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

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

- Is the MTD sensitive to heavy or fine sediment loadings, and is pretreatment required?
- Under what circumstances is the MTD 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? Is the filter medium 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?

5.2.4.9 -- TER -- Description: References

List any sources of published information, including websites, cited in the technology description section. List sources alphabetically. Follow the format style used for references included within the design specifications information for post-construction, non-proprietary BMPs listed on the Clearinghouse website.

5.2.5 -- TER -- Test Methods and Procedures Used

Include descriptions of how the assessment data were obtained. For all laboratory and field tests, the author of the TER shall provide the following information:

- Specifics of the MTD used in the assessment (model number if applicable, size).
- All procedures for obtaining data as described in the approved QAPPs, including a description of any deviations from this procedure during the assessment.
- Information on QA/QC as described in the approved QAPPs and followed during testing.
- Inspection protocols used to determine when maintenance was needed. All maintenance activities shall be logged and included.
- Summary of the maintenance procedures implemented during the course of the performance testing.
- The method used to calculate performance.

For all MTDs seeking approval (at either the **PUD**, **CUD**, or **GUD** level), whether the testing occurred in the laboratory or in the field, include the requested information below when applicable:

- Influent and effluent requirements of PSD, TSS, and SSC, including 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 QA/QC 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 approval levels (**PUD**, **CUD**, and **GUD**). When applicable, follow the instructions under **Section 1.6 -- Protocol Limitations, Release of Liability, and Disclosure** for how to handle proprietary information that is to be kept confidential.

1. Granulometric media properties:
    a. Representative media size gradation, i.e., media size distribution and statistical indices;
    b. Representative media specific gravity; and
    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, characterize field sites by including the following information:

- General description of where the testing occurred (street, city, state, zip).
- Site information shall include a site map, land-cover type, land-use activities, location of land-use activities, 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.
- Narrative that describes any special circumstances (e.g., pretreatment, bypass conditions, retention/detention facilities).
- The method used for sizing the MTD for the specific testing location.
- The time period that testing occurred for each test site., the sequence of storms, including missed events

If laboratory tests were performed for **PUD** approval, or included for supplemental information for a **CUD** or **GUD** approval, include the following information:

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

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

5.2.6 -- 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. Show calibration results of flow metering systems.

5.2.7 -- TER -- Data Verification and Validation

Include the certification statements certifying that the data have been verified and validated. These statements shall be signed by the responsible personnel within the testing organization or as part of external data verification and validation. Also, include the data validation report, which is to be written by person(s) independent of the activity which is being validated. Refer to EPA's *Guidance on Environmental Data Verification and Data Validation* (U.S. EPA 2002a) for practical advice on implementing data verification and validation.

5.2.8 -- TER -- Data Summary

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

5.2.8.1 -- TER -- Data Summary: Field Testing

Report the number of storms monitored, longest continuous sequence of storms sampled, and the number of sets of back-to-back storms monitored. Using the validated data, complete a **Stormwater MTD Demonstration Site Summary** form (available from the Virginia Stormwater BMP Clearinghouse website) for each field test site. When reporting the PSD, include the entire distribution and specify D_{50}. Include additional data of value to understand the performance results and/or quality control measures. Include individual storm reports in the appendices of the TER (see **Section 5.2.11 -- TER – Appendices**).

Maintenance data are required. Quantify the impact of maintenance activities or lack thereof on performance. The Department recommends the use of a graphical representation of pollutant removal over time highlighting the times when and how maintenance was performed to verify maintenance cycles.

5.2.8.2 -- TER -- Data Summary: Laboratory Testing

Include laboratory testing results in the TER at the conclusion of performance testing. 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 MTD 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 MTD, include information about the particle-size distribution of the test material (entire distribution, specify D_{50}).
- Report the number of test runs.
- Summarize the specific settings of each test run, e.g., flow rate, run times, and loading rates.
- Include data to show pollutant removal of phosphorus and sediment. If the MTD performance was tested under different conditions (e.g., different flow rates, filter material, etc.), be sure to show data results for each tested condition. Determine the percent capture of the various sized particles under the performance claim conditions (e.g., flow rate).
- At the option of the proponent, additional constituents (such as TN or dissolved nitrogen, metals, etc.) may be reported. However, the intent to assess the MTD for removal of these constituents shall be disclosed in the QAPP. Whereas no removal credit can be awarded for these constituents at this time, the data may be made available if the VTAP is extended to other pollutants. This optional data will NOT be reviewed by the evaluator, the committee, or the Department at this time.
- For MTDs considered for in-line (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).

5.2.9 -- 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 MTD performance varies with factors such as antecedent dry period, storm magnitude, and/or storm intensity. For all systems, address flow balance and provide justification for any loss of flow between the inflow and outflow.

5.2.10 -- TER -- Conclusions, Recommendations, and Limitations

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

- All conclusions related to performance testing.

- Expected MTD performance for typical land uses. Recommendations concerning how best to site the MTD relative to factors such as hydraulic grade and space constraints.
- Recommendations pertaining to the operation and maintenance (O&M) procedures of the MTD.
- Frequency with which maintenance is needed.
- Special disposal requirements.
- Site limitations that would preclude the use of the MTD.
- Limitations on the use or installation of the MTD, including information about anticipated performance in relation to design, site conditions, storms, and/or climate. 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, it is recommended that the proponent's technical advisor evaluate the overall performance of the design. The Department also recommends that the technical advisor 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/qa_docs.html.

5.2.11 -- TER -- Appendices

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 shall include:

- **General information** -- storm name, site location, system description, event date, date of last maintenance, antecedent conditions, unusual circumstances associated with the storm (e.g., a large storm that impacts the drainage area, etc.)
- **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 shall 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, pollutant removal (calculated per **Appendix C -- Pollutant Removal Calculation Methods**), and reported detection limits.

Additional data may be provided in the TER appendices as well. Include any information requested by the evaluators in the appendices.

5.3 -- 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.”

5.4 -- Status Reports

Once awarded an official **PUD** or official **CUD**, the proponent shall submit quarterly status reports to the Department. Upon receiving an official **PUD** or official **CUD** and selecting a testing site, the proponent shall develop a list of milestones and targeted dates of completion. The milestones are to be developed from the Department-approved QAPP and be based on expected achievements. Quarterly status reports are due to the Department for the preceding 3-month period (see **Section 3.1 -- Overview of Virginia Technology Assessment Protocol and Timeline**).

The proponent shall follow the milestone chart and (1) highlight which achievements were met during the quarter; (2) summarize the progress made during the 3-month reporting period; (3) report any setbacks encountered; and (4) summarize the data obtained during the reporting period when available and describe any trends in the data.

In the status report, the proponent shall evaluate whether undesirable trends are occurring and report on the response to the findings. If undesirable trends become evident, the proponent shall begin identifying and implementing corrective actions as needed.

The status reports shall be used by the Department to track progress. If undesirable trends become evident, the Department may call for the suspension or cancellation of the approval (see **Section 3.1 -- Overview of Virginia Technology Assessment Protocol and Timeline**). The Department will make evaluations on a case-by-case basis.

Each status report shall include the following information:

- Title of the project
- Name of proponent submitting the report
- Date of the reporting period
- Location(s) of installments of the MTD in Virginia during the reporting period
- Location of field test site(s)
- 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

The proponent shall submit an electronic version, on a digital Compact Disc or as an e-mail attachment, to the Department at the address listed on the Virginia Stormwater BMP Clearinghouse. For assistance, please contact the Department by using the contact information listed on the Virginia Stormwater BMP Clearinghouse.

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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

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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 are not available 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 that 25% (0.25). Using a simple trial-and-error process 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 α = 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 an approval 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 size[1]

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:

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Appendix B -- 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 large-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 ± 2°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°C ±2 degrees)
__ Analytical balance (0.01 mg accuracy)
__ Wash bottle
__ Reagent-grade water

Procedure

- Dry glass filter in drying oven at 90 ± 2°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 ± 2°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 C -- Pollutant Removal Calculation Methods

Modified from

Center for Watershed Protection's

Tool 8: BMP Performance Verification Checklist Appendices
2008

Pollutant Removal 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. To fully understand stormwater treatment, all of the runoff needs to be accounted for (e.g., untreated runoff, treated runoff, and bypassed flows). 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 the DCR (Table G.1). 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.

Table C.1. Methods to estimate pollutant removal credit (From Center for Watershed Protection 2008; compiled from ASCE and U.S. EPA 2002)

Method	Type of Method	Formula	Comments
Efficiency Ratio (ER)	**Concentration**	$ER = 1 - \frac{Average\ outlet\ EMC}{Average\ inlet\ EMC}$ Where the EMC = $\frac{\sum_{j=1}^{n} CiVi}{\sum_{j=1}^{n} Vi}$ Where: *Ci* = event inflow concentration; *Vi* = event inflow volume	• 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**	$SOL = \frac{sum\ of\ outlet\ loads}{sum\ of\ inlet\ loads}$ Where the Load = C*i*V*i* *Ci = average concentration within period i; Vi = volume of flow during period i*	• 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