Guidance for Evaluating Emerging Stormwater Treatment Technologies

Technology Assessment Protocol - Ecology (TAPE)

WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

October 2002 (Revised June 2004)
Publication Number 02-10-037

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ACKNOWLEDGMENT

This guidance document was developed with the considerable assistance of a Technical Review Committee (TRC). Ecology appreciates their efforts and the sharing of their expertise. Members included:

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INTRODUCTION

In August 2001, the Washington Department of Ecology (Ecology) published a revised Stormwater Management Manual (SWMM) for Western Washington (Ecology 2001) which includes stormwater treatment facility design criteria, performance goals, and a process for evaluating the performance of stormwater treatment facilities. The Ecology manual can be found online at http://www.ecy.wa.gov/programs/wq/stormwater/index.html.

Volume V, Chapter 12 of the SWMM is devoted to emerging treatment technologies. In contrast to public domain practices such as biofilters, ponds, and sand filters, Volume V does not provide criteria for the selection and sizing of emerging technologies. It would be impracticable to include such information in the Ecology manual because the technologies and the knowledge base are rapidly evolving. However, because local governments are being asked to review and approve emerging treatment technologies, guidance is needed for an acceptable protocol and a process for evaluating and accepting new treatment technologies.

PURPOSE OF THIS GUIDANCE DOCUMENT

This guidance document's primary purpose is to establish a testing protocol and process for evaluating and reporting on the performance and appropriate uses of emerging stormwater treatment technologies. This document is also intended for use in evaluating public domain practices (e.g., biofilters, wet pool facilities, sand filters) possibly resulting in changes to the design standards for these practices in the SWMM. Local governments statewide can use the designations posed on Ecology's website where applicable, depending on local conditions.

Note: Due to the wide spectrum of potential chemical treatment technologies that may be submitted for review, this guidance contains direction that may not apply to all applicants. Initial submittals should include all of the data the applicant believes is appropriate for their technology and the rationale for submitting that data. Also a vendor or manufacturer may request a preliminary meeting with the CTRC and Ecology to discuss which portions of the CTAPE would apply for their technology. On a case-by case basis the review committee will request additional information as determined by an evaluation of the impact the technology could potentially have on the environment.

ECOLOGY'S INTENT REGARDING THE EVALUATION OF EMERGING TECHNOLOGIES

Ecology intends that, in all situations where stormwater treatment is required, local governments consider those emerging technologies that have been tested, evaluated, and received an appropriate designation according to this document. However, because adequate local installation and testing are needed in order to obtain performance information, local jurisdictions, industrial/commercial establishments, and consultants are encouraged to pursue limited use of emerging technologies that have Pilot Level or Conditional Short-Term Use Designations. A subsequent section explains these designations. The responsible party should also demonstrate that the installation and testing are part of a program designed to attain a General Use Level Designation.

Ecology plans to publish assigned development designations along with a summary of the supporting data at its website for statewide distribution.

TECHNOLOGY EVALUATION PROCESS

SUMMARY

The technology performance evaluation process consists of the following elements:

- Implementation of a quality assurance project plan (QAPP) by the project sponsor
- Submission of a technology evaluation engineering report (TEER) to Ecology and the Technical Review Committee (TRC) by the project sponsor.
- Review of the QAPP and TEER by Ecology and the TRC.
- Publishing pertinent information and determinations by Ecology at Ecology's website.

The laboratory and field testing should be based on the protocol in this guidance document. Other protocols, including modifications of any specific procedures, judged by the responsible professional to be more applicable for the technology, may be submitted to Ecology and the TRC for consideration and possible approval.

ROLES AND RESPONSIBILITIES

Technical Review Committee (TRC)

The TRC includes representatives from Ecology and eastern and western Washington local governments.

The TRC’s duties are:

- Assisting Ecology in reviewing the QAPP and other submittals.
- Providing oversight review of technology evaluation engineering reports (TEERs) per the technology assessment protocol (TAPE) including inspections of full-scale operating treatment facilities.
- Providing recommendations and assessments to Ecology of the appropriate emerging technology use level designations for posting at Ecology's website.
- Meeting, as needed (two to four times per year) to review new information and revise/update the TAPE, fact sheets, and website.
- Interacting with Ecology staff to assess how well the TAPE process satisfies Ecology’s stormwater treatment BMP selection objectives.

Ecology

Ecology’s role is as follows:

- Participating in TRC activities.
- QAPP review and approval.
- Providing oversight and analysis of the TEER reviews and other relevant reports to ensure consistency with Ecology’s western (August 2001) and eastern (when published) Washington stormwater manuals.
- Posting relevant information at the Ecology website.

Vendor/Manufacturer of the Technology

Performance Testing and Reporting

The vendor/manufacturer prepares the quality assurance project plan (QAPP) based on the TAPE and submits it to Ecology and the TRC prior to implementation. The TAPE's goal is to obtain accurate and relevant data to assess vendor performance claims and enable comparison to Ecology SWMM performance standards. Vendors are strongly encouraged to retain a consultant or an experienced agency professional (third party) to: 1) oversee QAPP preparation and implementation, 2) prepare a data validation report verifying that monitoring was conducted in accordance with the approved protocol and the QAPP, and 3) prepare the TEER (see page 8). ETV verification will depend on third party testing.

However, at a minimum, the following work must be performed by an independent professional:

- Complete the data validation report.
- Prepare a TEER summary, including a test results summary and conclusions compared with the supplier's performance claims.
- Provide a recommendation of the appropriate technology use level.
- Recommend relevant information to be posted on Ecology's website.
- Provide additional testing recommendations, if needed.

Performance Claims

The QAPP must clearly identify the vendor's performance claims including:

- Reduction of pollutants from stormwater runoff.
- Applications of the technology (runoff from roadways, high-use sites, commercial areas, industrial facilities, residential areas, etc.) to be verified.
- Uses of the technology (basic, enhanced, and/or pretreatment; oil, TPH, metals, and/or phosphorus removal; treatment train, retrofits, etc.).
- The basis for sizing the device establishing a test plan, and listing the pollutant constituents that will be used to evaluate performance.

Performance claims may be qualitative (e.g., advantages over other technologies, Operations and Maintenance, etc.) and/or quantitative (e.g., load reductions and removal efficiencies for specific pollutants or categories of pollutants). See Appendix A for calculation methods.

Cost Consideration in Conducting the Verification Program

The financial burden for completing a development program, including the laboratory and field testing, lies with the supplier/manufacturer of the emerging technology. Neither Ecology nor the TRC can provide funding for this work.

However, Ecology recognizes the need to minimize the cost of implementing a verification program. To the extent applicable, the following are ways to minimize cost yet provide sufficient verification data:

- Submit data collected using protocols other than the TAPE, such as Environmental Technology Verification (ETV), Environmental Technology Evaluation Center (EvTEC), and Technology Acceptance and Reciprocity Partnership (TARP). (*Note: Reciprocity agreements between the states and ETV are under consideration.)*
- Use laboratory and controlled field testing to the maximum extent practicable and justifiable.

- Carefully select field test sites so that evaluations based on the TAPE will be efficiently conducted and the results can be applied elsewhere, consistent with other protocols.
- Carefully prepare the QAPP so that the need to conduct additional sampling will be kept to a minimum.
- Periodically evaluate the results to check for statistical significance and acceptability. For example, the number of tested storms required by this protocol ranges from 12 to 35 events. It therefore would be prudent to review the data after 12 events to see if they are sufficient.
- For statistical significance determinations, consider pooling of data from several sites per application or for several applications, if justified. Data from more than one site can be combined (pooled) to meet the 12-35 events criterion provided that the tributary drainages are from similar land uses and the pollutant concentration variability is reasonably comparable.
- Evaluate intra-event data (for relatively constant flow periods within a storm event) separately from the short-duration data along with the event mean data. These intra-event data may be more meaningful for performance assessment, and there could be multiple “storms within storms,” enabling the vendor to more quickly attain its 12 to 35 storm and flow rate event goal.
- Submit interim status reports to Ecology and the TRC and request a sufficiency opinion.
- Propose/implement other cost saving measures based on the Best Professional Judgment (BPJ) of the Project Professional.

ECOLOGY-SPECIFIED TREATMENT PERFORMANCE GOALS

Ecology’s SWMM specifies basic, enhanced, phosphorus, and oil treatment goals, as stated below. Details on these performance goals are provided in Volume V, Chapter 3, of the Ecology manual (Ecology, 2001). Emerging technology suppliers claiming pollutant removal effectiveness should demonstrate (based on data reported in the TEER) that the treatment performance goals are achieved. The performance goals will depend on whether the technology is a pretreatment device, part of a treatment train, or a basic or enhanced stand-alone facility. As part of a treatment train, the performance of the entire treatment train and its components should be evaluated. In addition, "factors other than treatment performance" are important and will be evaluated to determine the emerging technology’s appropriate use(s) (see Appendix B).

Basic Treatment

Ecology’s basic treatment menu facility choices are intended to achieve a goal of 80 percent removal of total suspended solids for influent concentrations that are greater than 100 mg/L, but less than 200 mg/L. For influent concentrations greater than 200 mg/L, a higher treatment goal may be appropriate. For influent concentrations less than 100 mg/L, the facilities are intended to achieve an effluent goal of 20 mg/L total suspended solids. Flows in excess of the water quality design flow or volume can be bypassed around the facility. The performance goal applies:

- to stormwater with a typical particle size distribution;
- on an annual average basis to the entire discharge volume (treated plus bypassed); and
- to the water quality design storm volume or flow rate. (Ecology, 2001-Ch.4, Vol.V)

Enhanced Treatment

The enhanced menu facility choices are intended to provide a higher rate of removal of dissolved metals than most basic treatment facilities. The performance goal assumes that the facility is treating stormwater with dissolved copper typically ranging from 0.003 to 0.02 mg/L, and dissolved zinc ranging from 0.02 to 0.3 mg/L. Using available basic treatment BMP dissolved metals removal information (such as from vendors or the ASCE National Stormwater BMP Database) data collected for an “enhanced” BMP should demonstrate significantly higher removal rates than basic treatment facilities.

Phosphorus Treatment

The phosphorus menu facility choices are intended to achieve a goal of 50 percent total phosphorus removal for a range of influent total phosphorus (TP) of 0.1 to 0.5 mg/L.

Oil Treatment

The oil control menu facility choices are intended to achieve the goals of no ongoing or recurring visible sheen, and a daily average total petroleum hydrocarbon concentration no greater than 10 mg/L, and a maximum of 15 mg/L for a discrete (grab) sample.

Treatment Train, Retrofits, and Pretreatment Applications

Vendors/manufacturers are also encouraged to evaluate their products for use in treatment trains, pretreatment (including gross solids removal), or retrofit applications. While Ecology has no explicit performance standards for these other applications, a lesser performance (than required for basic treatment in stand-alone technologies) is acceptable. The following guidelines may be used for assessing technologies at less-than-basic treatment levels, including retrofits:

- Provides mostly coarse solids removal (> 500 microns) including all litter and debris.
- Improves the effectiveness, extends the useful life, or extends the maintenance cycle of a downstream treatment device or infiltration facility.
- Results in a more cost-effective treatment system.

The pretreatment menu is generally applied to:

- Project sites using infiltration treatment
- Treatment systems where needed to assure and extend performance of the downstream basic or enhanced treatment facilities.

The pretreatment menu facility choices are intended to achieve 50% removal of fine (50 micron-mean size) or 80% removal of coarse (125 micron-mean size) total suspended solids for influent concentrations that are greater than 100 mg/l, but less than 200 mg/l. For influent concentrations less than 100 mg/l, the facilities are intended to achieve effluent goals of 50 mg/l and 20 mg/l total suspended solids, respectively.

The performance goal applies to the water quality design storm volume or flow rate, whichever is applicable. The goal also applies on an average annual basis to the entire annual discharge volume (treated plus bypassed). The incremental portion of runoff in excess of the water quality design flow rate or volume can be routed around the facility (off-line treatment facilities), or can be passed through the facility (on-line treatment facilities) provided a net TSS reduction is maintained. The local government may require that treatment facilities engage a bypass at flow rates higher than the water quality design flow rate, as long as the reduction in TSS loading exceeds that achieved with initiating bypass at the water quality design flow rate.

EMERGING TECHNOLOGY DESIGNATED USE LEVELS

The TRC and Ecology will evaluate the application cover letter and report and determine a use level designation for each technology. The TRC will provide a draft report for vendor feedback prior to forwarding the use level designation to Ecology. Ecology will then review the TRC's recommendations and publish appropriate determinations on its website.

Note: This Ecology Stormwater Technology Verification Program is not intended to be used for conducting research on experimental devices. Ecology will not consider an application for a Pilot Level Designation (PLD), Conditional Use Designation (CUD), or a General Use Level Designation (GULD) unless the application includes sufficient performance data that clearly demonstrates acceptable feasibility and the likelihood that it will achieve desired performance levels at actual full-scale field conditions. Laboratory and/or field performance data obtained in other sates and using other protocols such as the ETV and TARP Protocols will be considered for PLD and GULD within the constraints of the TAPE.

Pilot Level Designation

For emerging technologies not currently in widespread use, the pilot level designation (PLD) allows limited use to enable field testing to be conducted (if a technology is currently in widespread use please refer to the "Conditional Short-Term Use Designations" section). Subject to limitations that Ecology may impose on the number and location of installations, the PLD enables the vendor to request local governments to allow limited use of the technology for the sole purpose of collecting additional field performance data.

Local governments may allow PLD technologies to be installed in new development or redevelopment situations provided that the vendor and/or developer agree(s) to conduct additional field testing based on the TAPE at all installations to obtain a general use level designation (GULD). Local governments that are covered by an NPDES permit must notify Ecology in writing when a PLD technology is proposed for new development or redevelopment. Other jurisdictions are also encouraged to notify Ecology when a PLD technology is proposed (***use the form in Appendix C***). All local governments are encouraged to require vendors to provide a performance guarantee stating that PLD facilities will be upgraded as necessary, and to the maximum extent practicable, to meet Ecology performance goals.

Local jurisdictions may use PLD or unapproved technologies in retrofit situations but are encouraged to test their performance in at least some of those retrofit applications. In fact, testing in retrofit situations may be the preferred option since sites with higher pollution levels may be more suitable for quantifying a pollutant reduction.

To obtain a PLD, the vendor must provide a letter with a supporting report that includes the following information:

- The cover letter should include performance claims for specific land uses and identify the target pollutants.
- A detailed technology description, including its chemical, physical, and/or biological treatment functions (i.e., how it works and how it removes pollutants) sizing methodology, recommended maintenance procedures, and expected treatment capabilities.
- Description of system hydraulic capacity and performance.
- Updated field, laboratory, modeling and other data in support of the performance claims.

Note: To the extent applicable, the report's content should be consistent with the TEER described below.

A PLD will be issued if, based on the information provided by the vendor, the technology may reasonably be expected to achieve Ecology's performance standards for one or more target pollutants. Within six months of receiving a PLD, the vendor must submit a QAPP that meets the TAPE's General Use Level Designation requirements. After the QAPP has been reviewed and approved by the TRC and Ecology, the vendor will have 18 months to implement the QAPP and submit the TEER report.

General Use Level Designation

The general use level designation (GULD) confers a general acceptance for the specified applications (land uses). Technologies with a GULD may be used anywhere in western Washington, subject to Ecology conditions. GULD technologies may also be used in eastern Washington depending on local conditions and needs. Ecology plans to include GULD-designated technologies in future stormwater manual updates.

To obtain a GULD the technology must meet both of the following criteria based on information in the TEER:

- The technology is expected to provide effective stormwater treatment achieving Ecology's performance goals for the target pollutants, if applicable, and as demonstrated by field testing performed in accordance with the TAPE; and,
- The technology is deemed satisfactory with respect to factors other than treatment performance (e.g., maintenance; see Appendix B for complete list).

Conditional Use Designation (Short-Term)

The TRC will consider granting a conditional use designation (CUD) under the following circumstances:

- An emerging technology is in widespread use in the Pacific Northwest and/or on a national basis, and the manufacturer has a substantial base of performance data, although a portion of the data may not satisfy TAPE criteria, or
- An emerging technology is in limited use, has limited performance data that satisfy TAPE criteria, and is deemed to be functionally equivalent to another emerging technology for which the TRC has granted a CUD or GULD,
- And, the TRC finds it is likely that, after completing additional laboratory and/or testing meeting TAPE criteria, the technology will be awarded a GULD.

Technologies that are granted a CUD will be allowed continued use for a specified time period, during which the field and laboratory testing necessary to obtain a GULD must be completed and a TEER must be submitted to Ecology and the TRC. Each CUD designation document may include conditions which the manufacturer must consider in completing the monitoring, design, O&M criteria, etc. for the technology.

Vendors desiring a CUD should submit an application letter and supporting report to Ecology and the TRC. CUD application requirements include all items described above for the PLD, plus a list of the number and locations of existing installations in the United States and Canada, with detailed information for Washington, Oregon and British Columbia. The vendor must also submit a QAPP that meets TAPE requirements, either with the CUD application or within three months from the date of the CUD application. Following QAPP approval and appropriate CUD designation (with possible conditions) by Ecology, the vendor will then have a maximum of 24 months to implement the QAPP and submit a TEER to Ecology and the TRC. Following TEER review, Ecology will determine whether to award a GULD, and will designate any appropriate use restrictions. At that time, the CUD will be revoked and replaced with the GULD if supported by the TEER. Failure to submit the QAPP or TEER by their deadlines, or to demonstrate satisfactory progress during the 24-month testing period, may result in Ecology posting the cancellation of the CUD at its website. Loss of the CUD may result in recommending immediate prohibition on future installations, which will not be lifted until applicable performance levels are satisfied.

Ecology and the TRC will review the information provided by the vendor to determine appropriate technology applications (e.g., pretreatment, basic treatment, enhanced treatment, phosphorus treatment, oil treatment) and issue the CUD, with appropriate restrictions, if applicable. Ecology will maintain a CUD vendor list on its web page to assist local jurisdictions in identifying accepted technologies. Granting CUDs will be at Ecology discretion using BPJ in reviewing the information submitted by the vendor. Technologies not granted a CUD would automatically be considered for a PLD.

In summary, publishing a CUD at Ecology's website will depend on the following:

- An application to Ecology and the TRC for a CUD which is accompanied by an PLD-level engineering report;
- The application signed by a responsible officer (s) of the company(ies);
- Timely submission of a QAPP for obtaining a GULD; and
- A determination by Ecology that the technology is likely to attain GULD status, based on the CUD application and the QAPP.

Technology Evaluation Engineering Report (TEER) Content

At a minimum, the TEER must contain the following information:

- A statement of the QAPP objectives(s) including the vendor's performance claims for specific land uses and applications in western and eastern Washington.
- All deliverables specified in the QAPP.
- A thorough technology description, including sizing methodology, flow diagrams and appropriate illustrations.
- All relevant performance test results, statistical analyses, factors other than performance, and operating and maintenance activities including all the information required for a PLD. A discussion of results obtained during each storm is desirable.
- Any available non-standard data (data not collected per the TAPE, such as laboratory testing, out-of-state testing, or field performance testing with real storms not meeting protocol guidelines).
- Whole effluent toxicity data if chemical component(s) is/are added to the stormwater discharge either directly or indirectly.
- Conclusions and recommendations including the technology's development level, recommended operating and maintenance (O&M) procedures, pretreatment requirements, and use limitations.
- Capital and projected annual costs, including O&M costs.
- An executive summary.
- Recommended information to be posted at Ecology's website.
- Additional testing recommendations, if needed.

Number of Test Sites

Testing at multiple sites is recommended. Sites should reflect the technology's intended applications (specific land uses). The number of storm or discrete flow rate sampling events may vary between 12 and 35 per application, depending on the statistical variability. Data from more than one site can be combined (pooled) to meet the 12-35 events criterion provided that the tributary drainages are from similar land uses and the pollutant concentration variabilities are reasonably comparable. Statistical factors such as confidence levels (up to 95%), power curves, and regression equations should be considered in the statistical analysis. For guidance on the appropriate statistics, refer to Appendix D.

Requesting/Revising Use Level Designations

A technology's use level designation may be changed by Ecology and posted at its website based upon new information. Vendors seeking a technology use level designation by Ecology should mail their submission to the following address:

Washington State Department of Ecology
Water Quality Program
P.O. Box 47600
Olympia, WA 98504-7600

Confidential Information Submitted by the Applicant

Certain records or other information furnished to Ecology may be deemed confidential pursuant to RCW 43.21A.160 if those records or information relate to the processes of production unique to the owner or operator thereof, or may affect adversely the competitive position of such owner or operator if released to the public or to a competitor, and Ecology has granted a request for confidentiality. In order for such records or information to be considered confidential, the owner or operator of such process or production may certify that the records or information relate to the processes of production unique to the owner or operator, or would affect adversely the competitive position of such owner or operator if released to the public or to a competitor, and request that such records or information be made available only for the confidential use of Ecology. Upon receipt of such request the director of Ecology or his/her designee will consider the request, and if deeming such records or information confidential would not be detrimental to the public interest and would otherwise be in accordance with Ecology's policies and purposes, may grant the request for confidentiality. You may request return of material if your request for confidentiality is denied.

TECHNOLOGY ASSESSMENT PROTOCOL-ECOLOGY (TAPE)

OBJECTIVES OF THE TEST PROTOCOL

The objectives of this protocol are to characterize, with a reasonable level of statistical confidence, an emerging technology's effectiveness in removing pollutants from stormwater runoff for an intended application and to compare test results with vendor's claims.

QUALITY ASSURANCE PROJECT PLAN (QAPP)

Vendors/manufacturers need to carefully plan and execute monitoring programs. Before initiating testing, a quality assurance project plan (QAPP) must be prepared based on this protocol. The QAPP must be submitted for Ecology and TRC review before conducting field tests[1].

The QAPP must specify the procedures to be followed to ensure the validity of the test results and conclusions. A person with good understanding of analytical chemistry methods should develop the QAPP in consultation with the analytical laboratory. The QAPP author should also be knowledgeable about field sampling and data validation procedures. *(Note: Refer to Role and Responsibilities section for additional guidance).*

Ecology (2001) QAPP guidance includes the following basic elements:

- Title Page with approvals;
- Table of contents;
- Project organization and schedule;
- Background information and information about the technology to be tested;
- Sampling design, including field procedures, sampling methods;
- Method quality objectives, including statistical goals;
- Laboratory procedures;
- Field and laboratory quality control;
- Data management procedures;
- Data review, verifications and validation; and
- Interim progress report(s) during the testing program.

PROJECT ORGANIZATION AND SCHEDULE

The QAPP must specify the name, address, and contact information for each organization and individual participating in the performance testing. Include project manager, test site owner/manager, field personnel, consultant oversight participants, and analytical laboratory that will perform the sample analyses. Identify each study participant's roles and responsibilities and

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[1] *Note: To assess emerging technologies, the TRC and Ecology has updated the existing draft protocol developed by the American Public Works Association for testing stormwater treatment technologies (APWA 1999). We have coined the term "TAPE," which stands for Technology Assessment Protocol—Ecology, for this updated protocol. If a vendor wishes to use a protocol other than the TAPE, it must be submitted to the TRC and Ecology for review and approval prior to initiating the sampling program.*

provide key personnel resumes. In addition, provide a schedule documenting when the vendor’s equipment will be installed, the expected field testing start date, projected field sampling completion, and final project report submittal. Ecology and the TRC will review and approve the QAPP prior to the start of field testing. It is recommended that time be allocated for initial startup and testing of the treatment system and monitoring equipment. Vendors should allow up to three months for QAPP review and approval.

INFORMATION ABOUT THE TECHNOLOGY

At a minimum, include the following information to support the requested use designation:

- Describe how the technology functions in treating stormwater runoff. Include information about physical, chemical, or biological treatment processes such as filtration, adsorption/absorption, settling, or inertial separation that may be involved in the treatment process.
- Physically describe each treatment system component. Include a description of the specific unit to be tested as well as information about how this unit relates to other units offered by the vendor. The physical description should include: 1) engineering plans/diagrams showing each of the functional components, construction materials (including filter media, absorbent , or other media that may be part of the treatment system), equipment dimensions, and each component’s capacity (e.g., hydraulic capacity, sediment storage, floatables/debris storage); 2) explain any site or installation requirements such as necessary soil characteristics, hydraulic grade requirements, depth to groundwater limitations, or utility requirements; and 3) pretreatment recommendations, if necessary.
- Summarize available performance information. This section should state the vendor’s claims regarding the system’s ability to remove or reduce specific stormwater pollutants for specific land uses. Include any bench-scale testing to support the performance claims. Wherever possible, include information about anticipated performance in relation to climate, design storm, and/or site conditions. This information will be reviewed to evaluate use designation as well as to determine specific pollutants to be analyzed during the field test.
- Describe the manufacturer’s recommended operation and maintenance procedures, including both preventative maintenance procedures to be implemented during the course of the field test as well as long-term maintenance. Provide a description of personnel, supplies, replacement materials and/or parts availability (e.g., filter media) and equipment needed to operate and maintain the facility. Include a recommended maintenance schedule and identify access ports and dimensions provided to facilitate maintenance. Also, identify any special disposal requirements associated with spent media, absorbents, or other material to be generated during routine cleaning/maintenance operations.
- Include raw material specifications for all treatment media to ensure the quality control of this fundamental component.
- Summarize any limitations or pretreatment requirements of the technology, as well as any advantages over approved technologies.

SAMPLING DESIGN CONSIDERATIONS

This section describes test procedures that can be used to evaluate vendor's performance claims and consistency with Ecology's "average annual basis" and "water quality design storm flow rate" performance goals (see Appendix A for calculation methods). This protocol specifies that field testing be conducted for 12 to 35 events. Sizing of the test facility must be based on meeting applicable performance goals at the design flow rate coinciding with treating at least 91 percent of runoff volume, using an Ecology-approved continuous simulation model such as HSPF or the Ecology Hydrology Model. It is recommended that sampling events be evenly distributed over the monitoring period to capture seasonal influences on storm conditions and system performance.

Test Site Characterization

Select field test sites that are consistent with the technology's intended applications (land uses) and geographical location (eastern and western Washington) that will provide influent concentrations typical of stormwater for those land use types[2]. Describe how the treatment technology was selected and designed for the specific field test site. Include manufacturer sizing methodology and any deviations from sizing methods. Include the following information on the test site:

- Field test site catchment area, tributary land uses (roadway, commercial, high-use site, residential, industrial, etc.) and impervious cover.
- Describe potential pollutant sources in the catchment area (e.g., parking lots, roofs, landscaped areas, sediment sources, exterior storage or process areas).
- Baseline stormwater quality information to characterize conditions at the site. For sites that have already been developed, it is recommended that baseline data be collected to provide a sizing basis for the device, and to determine whether site conditions and runoff quality are conducive to performance testing.
- Site map showing catchment area, drainage system layout, and treatment device and sampling equipment locations.
- Catchment flow rates (i.e., water quality design flow, 2-year, 10-year, and 100-year peak flow rates) at 15-minute and 1-hour time steps as provided by an approved continuous runoff model.
- Make, model, and capacity of the treatment device.
- List the closest receiving water body location and description.
- Identify bypass flow rates and/or flow splitter designs necessary to accommodate the treatment technology.
- Describe pretreatment system, if required by site conditions or technology operation.
- Determine site adequacy for sampling, flow measurement access, and telephone/AC power, if needed.
- Describe any known adverse site conditions such as climate, tidal influence, high ground water, rainfall pattern, erosion, high spill potential, illicit connections to stormwater catchment areas, industrial runoff, etc.

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[2] Typical stormwater contains about 100 mg/L TSS, 0.33 mg/L total phosphorus, 1.5 mg/L total Kjeldahl nitrogen, 0.034 mg/L total copper, 0.144 total lead, and 0.16 mg/L total zinc (EPA 1995). As a guideline, pollutant concentrations in stormwater at field test sites should be within about a factor of three of these levels.

Storm Event Criteria

The following vendor equipment field testing criteria have been established:

Feature	Explanation	Criteria
Number of events, minimum	Also depends on statistical evaluation	12-35 events per application (land use)[1] (see Appendix F on statistics)
Minimum storm depth	Total rainfall amount during the sampling event	0.15 inches
Storm start/end (antecedent dry-period)	Defines the storm event's beginning and end as designated by minimum time interval without significant rainfall	6 hours minimum with less than 0.04 inches of rain
Minimum storm duration	Shortest acceptable runoff duration	1 hour
Minimum storm intensity	Lowest intensity that qualifies as a rainfall event.	None, as long as above criteria are met[2]

1. Applies to flow-weighted and discrete flow rate (including design flow rate) composite sampling. Data from more than one site can be combined (pooled) to meet the 12-35 events criterion provided that the tributary drainages are from similar land uses and the pollutant concentration variability is reasonably comparable.
2. As a guideline, average intensities should exceed 0.03 inches per hour of at least half the sampled storms. In order to assess performance on an annual average basis, samples will need to be collected over a range of rainfall intensities encountered during an average year. Collecting a range of influent concentrations would be best done over four seasons as these results will tend to reflect different antecedent dry periods.

Stormwater Field Sampling Procedures

This section describes field sampling procedures that will be implemented to ensure the quality and representativeness of the collected samples. Included in this discussion are sampling methodology (e.g., discrete versus composite sampling), flow monitoring, target pollutant selection, sample handling and preservation, and field QA/QC.

Sampling methods. Samples must be collected using automatic samplers, except for chemical constituents that require manual grab samples (e.g., NWTPH-Dx). Teflon tubing must be used if samples will be analyzed for organic contaminants. To use automatic sampling equipment for insoluble TPH/oil, a determination is needed, supported by appropriate data, that any TPH/oil adherence to the sampling equipment is accounted for and meets QA/QC objectives. *(Note: ETV Program has requested USEPA to conduct a study of this issue and provide their recommendations).* The responsible project professional should certify that the sampling equipment and their location is likely to achieve the desired sample representativeness, aliquots, frequency, and compositing at the desired influent/effluent flow conditions.

The following three sampling methods have been identified for evaluating whether new treatment technologies will meet the Ecology stormwater treatment goals:

1. Automatic flow-weighted composite sampling. Samples are collected over the storm event duration and composited in proportion to flow. This sampling method will generate an event mean concentration and can be used to determine whether the treatment technology meets Ecology's 80 percent TSS removal on an average annual basis goal. For this method, samples

should be collected over the entire runoff period. As a guideline, at least 10 aliquots should be composited, covering at least 75 percent of each storm's total runoff volume up to the design storm volume.

2. Discrete flow composite sampling. For this method, program the sampler to collect discrete flow-weighted samples. Samples representing relatively constant inflow periods (e.g., less than 20 percent variation from the median flow) are combined to assess performance under specific flow conditions. The monitoring approach must also address the effect of lag time within the device that would affect the comparability of influent and effluent samples that are paired for purposes of evaluating a particular flow rate. One way to achieve this is to set the flow pacing so that each discrete sample bottle fills when the total runoff volume passing the sampler is equal to 8 times the treatment unit's detention volume. Other ways to account for lag time may also be considered.

This method is suitable and necessary for flow-through devices (e.g., minimal hydraulic residence time at design flow) and can be used to determine whether the treatment technology achieves Ecology's goal of 80 percent TSS removal at the design hydraulic loading rate. For this method, samples should be collected over a flow range that includes the manufacturer's recommended treatment system design flow rate. Other flow ranges may be sampled if needed to characterize the efficiencies of the device over a reasonable range of hydraulic loading rates. It is recommended that samples be well distributed over a range of flow rates from 50-110% of the device's design loading rate.

3. Combination method. For flow-through devices, a combination of the above two methods can also be used to evaluate both Ecology treatment goals. In this case, discrete flow composite samples would be collected as allowed during a single storm event and processed for analysis. The remaining bottles in the sampler can then be composited into a single flow-weighted composite sample to capture the entire runoff event for analysis. The results from the discrete flow composite samples and the single flow-weight composite sample can be combined mathematically to determine the overall event mean concentration.

Sampling locations. Provide a site map showing all monitoring/sampling station locations and identify the equipment to be installed at each site. To accurately measure system performance, samples must be collected from both the inlet and outlet from the treatment system. Sample the influent to the treatment technology as close as possible to the treatment device inlet. Samples should represent the total runoff from the catchment area and should not include debris and large particles (see the TSS definition in the target pollutants section). To ensure that samples represent site conditions, design the test site so that influent samples can be collected from a pipe that conveys the total influent to the unit. To avoid skewing influent pollutant concentrations, sample the influent at a location unaffected by accumulated or stored pollutants in, or adjacent to, the treatment device.

Sample the effluent at a location that represents the treated effluent. If bypass occurs, bypass flows must be measured and bypass loadings calculated using the pollutant concentrations measured at the influent station. In addition, be aware that the settleable or floating solids, and their related bound pollutants, may become stratified across the flow column in the absence of adequate mixing. Samples should be collected at a location where the stormwater flow is well-mixed.

Sampler installation, operation, and maintenance. In this section, provide a detailed sampling equipment description (make and model) as well as equipment installation, operation, and maintenance procedures. Discuss sampler installation (e.g., suction tube intake location relative to flow conditions at all sampling locations, field equipment security and protection), how the automatic sampler will be programmed (e.g., composite versus discrete sampling, proposed sampling triggers and flow pacing scheme), and equipment maintenance procedures. Samplers must be installed and maintained in accordance with manufacturer's recommendations. Indicate any deviations from manufacturer's recommendations. Provide a sampling equipment maintenance schedule. When developing the field plan, pay particular attention to managing the equipment power supply to minimize the potential for equipment failure during a sampling event.

Note: Tygon or teflon tubing may be used for sampling conventional parameters and metals.

Flow monitoring: Flow into and out of the treatment device must be measured and recorded on a continuous basis over the sampling event duration. Depth-measurement devices and area/velocity measurement devices are the most commonly used flow measurement equipment. The appropriate flow measurement method depends on the nature of the test site and the conveyance system. For offline systems or those with bypasses, it may be necessary to measure flow at the bypass as well as at the inlet and outlet. Describe the flow monitoring equipment (manufacturer and model number), maintenance frequency and methods, and expected flow conditions (e.g., gravity flow or pressure flow) at the test site. For offline flow describe the flow splitter to be used and specify the bypass flow set point. Identify site conditions, such as tidal influence or backwater conditions that could affect sample collection or flow measurement accuracy. It is recommended that sampling/monitoring sites be established at locations where gravity flow conditions exist, because it is difficult to obtain accurate flow measurements with existing flow measuring equipment under backwater conditions. Flow should be logged at a 15-minute or shorter interval, depending on site conditions.

Note: For offline facilities with a short detention time (< 15 minutes) at design flow conditions, flow measurement at the inlet may be used to represent outlet flow.

Rainfall monitoring: Rainfall should be measured and recorded at 15-minute intervals or less during each storm event from a representative site. Indicate the type of rain gauge that will be used (e.g., an automatic recording electronic rain gauge, such as a tipping bucket connected to a data logger, that records rainfall depths in 0.01 inch increments), provide a map showing the rain gauge location in relation to the test site, and describe rain gauge inspection and calibration procedures and schedule. Equipment must be installed and calibrated in accordance with manufacturer's instructions. At a minimum, the rain gauge should be inspected and if necessary, maintained after each storm event. In addition, the gauge should be calibrated at least twice during the field test period. If the onsite rainfall monitoring equipment fails during a storm sampling event, data from the next-closest representative monitoring station may be used to determine whether the event meets the defined storm criteria. Any deviations must be clearly identified in the TEER report.

Target pollutants*:* Pollutant constituent selection should be based on the vendor's performance claims and supported by the product literature. The performance claims may be evaluated in relation to one or more of the following parameters: total suspended solids (TSS), nutrients, heavy metals, petroleum hydrocarbons, and toxicity.

The vendor/manufacturer should also tailor the sampling regime to support the desired treatment level (basic, enhanced, phosphorus, oil, pretreatment/retrofit/treatment train). The following target pollutants should be analyzed depending on treatment level:

Treatment level	Preferred parameters	Recommended parameters
Basic and pretreatment	TSS, PSD[a], pH (lab)	TP, PSD[b], total and dissolved Cu and Zn, NWTPH-Dx, deicing salts[d]
Phosphorus	TSS, PSD[a], pH (lab), TP, orthophosphate	PSD[b]
Enhanced	TSS, PSD[a], pH (lab), hardness, total and dissolved Cu and Zn	PSD[b], total and dissolved Cd and Pb, NWTPH-Dx[c], toxicity testing
Oil	TSS, PSD[a], pH (lab), NWTPH-Dx[c] , Visible sheen (visual)	PSD[b],NWTPH-Gx[c]

a. Influent station.
b. Effluent station.
c. Grab sample only.
d. Roadway deicer, such as sodium and calcium chloride, should be included, if the deicer can significantly impact the performance of the device or it is a target pollutant.

Note: Unless otherwise specified, the parameters listed above are to be analyzed at both the inlet and outlet sampling stations.

See Appendix E for detailed listing of chemical analyses, methods, and reporting limits.

Sampling for TSS: This protocol defines TSS as matter suspended in stormwater, excluding litter, debris, and other gross solids exceeding 500 microns in diameter (larger than medium-sized sand). Conceptually this is consistent with the “Standard Methods” approach, which excludes large particles if it is determined that their inclusion is not desired.

To determine percent TSS reduction, the samples must represent the vertical cross section (be a homogeneous or well-mixed sample) of the sampled water at the influent and the effluent of the device. The selection of the sampling location, its homogeneity, and placement of and sizing of the sampler tubing in the stormwater must be conducted with care to ensure the desired representativeness of the sample and the stormwater stream. Also, the influent sample must represent only particles that are smaller than 500 microns to be considered as a stand-alone basic treatment device. This is important because influent particles greater than 500 microns are being considered similarly to debris and other gross solids, all of which should be pretreated and removed upstream of basic treatment devices. The sampling and analysis procedure for determining the particle size fraction below 500 microns can include sieve, such as US Standard #35 sieve, and instrumental analyses and should be selected by the site professional using BPJ.

In this Protocol we are applying the 80 percent TSS removal performance criterion at a discrete short timeframe for the low residence time treatment devices. This will be necessary for sizing and for performance verification. This short-term performance criterion is not intended to be a measurement of compliance. Event and seasonal means will be needed to confirm the sizing of long residence time devices and to provide useful data on the performance of the short residence time devices. Ultimately achievement of Ecology’s performance goals will be based on an annual average basis.

Particle Size Distribution (PSD): To meet the 80 percent TSS removal goal, treatment technologies must be capable of removing TSS across the size fraction range typically found in urban runoff. In western Washington, field data show most TSS particles are smaller than 125 microns.

To ensure a representative site and to size the treatment device, TSS and PSD should be analyzed prior to installing the treatment device. Literature and vendor data may also be used for sizing, as justified by the project professional. The PSD results of this test program will then be compared with the PSD used in sizing the treatment device to confirm the design basis of the device.

Of the analytical procedures available, Pitt recommends the Coulter Counter (model 3) although the newer laser-diffraction instruments may also provide sufficient sensitivity for particle sizes below 250 microns. Sieves may be also be used to quantify the particulate fraction beyond the range of the instruments. Due to the potential differences in precision among analytical procedures (Webb, 2000) the same analytical apparatus and procedure should be used for each evaluation test program. Refer to Pitt (2002) for a comprehensive discussion on PSD in stormwater runoff. A PSD analytical procedure recommended by the TRC using laser diffraction instrumentation and sieve analysis is attached (Appendix F).

Accumulated Sediment Sampling Procedures

As appropriate to demonstrate facility performance, and to confirm the stormwater sampling-based percent removal data, measure the sediment accumulation rate. Practical measurement methods would suffice, such as measuring sediment depth, immediately before each sediment cleaning and when testing is completed. The following sediment constituents should be analyzed:

- Percent total solids;
- Grain size;
- Total volatile solids;
- NWTPH-Dx;
- Total cadmium, copper, lead, and zinc; and
- Total phosphorus.

The sediment sample should be a composite from several grab samples (at least four) collected from various locations within the treatment system to ensure that the sample represents the total sediment volume in the treatment system. For QA/QC purposes, collect a field duplicate sample (see following section on field QA/QC). The sediment sample should be kept 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. Analyze the grain size using the methods described in Appendix E. Quantify or otherwise document gross solids (debris, litter, and other particles exceeding 500 microns in diameter). Volumetric sediment measurements and analyses should be useful in determining maintenance requirements, TSS mass balance, and whether the sediment quality and quantity are typical for the application.

Field QA/QC

The field QA/QC section describes the measures that will be employed to ensure the representativeness, comparability, and quality of field samples. Field QA/QC should include the elements listed below:

***Equipment decontamination*.** Describe how sampling equipment (sampler head and suction tubing) will be decontaminated between sampling events to prevent sample cross-contamination. It is recommended that the suction tube be replaced at least once during the test period and more frequently if runoff is highly contaminated.

Quality control samples. The following QC samples should be included in the QAPP:

Equipment rinsate blanks. Equipment rinsate blanks should be collected to verify that equipment is not a source of sample contamination. Equipment rinsate blanks are collected by passing reagent-grade water through clean equipment and collecting samples for chemical analyses. These samples are to be analyzed as regular samples with all appropriate quality control performed.

It is recommended that equipment rinsate blanks be collected at the inlet monitoring station where stormwater is expected to contain the highest contaminant concentrations. However, if the inlet station is difficult to access (e.g., confined space entry required), the rinsate blank may be collected from the outlet station. Two separate rinsate blanks should be collected during the initial equipment startup and testing, and at least one additional blank should be collected midway through the sampling program. More frequent blank samples may need to be collected if site conditions warrant (e.g., following an event with unusually high contaminant concentrations).

The equipment rinsate blank collection procedure should be described in the QAPP. Include a description of the location and number of samples that will be collected, sample collection and processing procedures, and sample documentation (e.g., length of time that sampler was in place prior to collecting the blank, how much stormwater passes through the sample prior to collecting the rinsate blank). At a minimum, rinsate blanks should be collected after at least one storm event has been sampled (to “contaminate” the equipment) and after the equipment has been decontaminated according to the procedures specified in the QAPP. The two initial blanks may be collected after a volume of stormwater similar to the volume that will be collected during a typical sampling event has been passed through the sampling equipment during the equipment testing process.

Ecology (2001) recommends that the equipment rinsate blank should be at a "not detected" level. If they are not, then they will have to be taken into account in determining whether the MQOs have been met. In the QAPP, describe corrective actions that will be taken (e.g., modifying decontamination procedures, replacing suction tubing) if contamination is found in the blank.

Field duplicate samples (for manual grab and sediment samples only). A field duplicate is a second independent sample collected at the same location. Field duplicates are primarily used to assess the variation attributable to sample collection procedure and sample matrix effects. Duplicates are required for sediment sampling and stormwater grab samples (but not for samples collected using an automatic sampler). The QAPP must include a description of techniques used to collect duplicate samples and specify the collection frequency. At a minimum, collect 10 percent field duplicate samples.

***Sample preservation and handling*.** Samples are to be preserved in accordance with Ecology (2001) methods, US EPA-approved methods (EPA 1983), or Standard Methods (APHA, AWWA, WEF 1999). Preservation must be provided during sample collection, as well as during transport. Describe how cooling the automatic samplers will be conducted to maintain low temperatures throughout the sample collection period.

Provide a table in the QAPP that lists sample container material, sample preservation, and holding time limits for the analyzed pollutants. See Ecology (2001) for sample container selection, preservation requirements, and target pollutant holding time limits. Pre-cleaned sample bottles should be obtained directly from the analytical laboratory. If the vendor proposes to obtain bottles from another source, provide a detailed bottle-cleaning procedure. Also, describe procedures that will be employed to label and track samples from collection through delivery to the analytical laboratory. Provide a sample chain of custody form in the QAPP.

Samples collected as discrete flow composites may need to be manually composited following the sampling event. If samples will be manually composited, describe compositing procedures to prevent sample cross-contamination. Also, certain parameters (i.e., NWTPH-Gx) may not be able to be composited, and must be collected as grab samples. Describe how these samples will be collected and at what intervals they will be collected during the storm event.

Equipment calibration. Describe the field equipment calibration schedule and methods, including automatic samplers, flow monitors, and rainfall monitors. The accuracy of the flow meters is very important so their calibration should be carefully conducted by the site professional in accordance with manufacturer's recommendations.

Recordkeeping*.* Maintain a field logbook to record any relevant information noted at the collection time or during site visits. Include notations about any activities or issues that could affect the sample quality (e.g. sample integrity, test site alterations, maintenance activities, and improperly functioning equipment). At a minimum, the field notebook should 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. Also, record measurements tracking sediment accumulation. In particular, note any conditions in the tributary basin that could affect sample quality (e.g., construction activities, reported spills, other pollutant sources). Provide a sample field data form in the QAPP.

METHOD QUALITY OBJECTIVES (MQOs)

MQOs are important for establishing consistent methods and procedures that are to be followed during sampling and analyses. MQOs help to ensure that the data quality will be adequate to verify a technology. The MQOs explain how the data are: 1) affected by systematic errors (bias) and 2) the precision of collected/analyzed data. This section should discuss the following elements:

- Bias: Describe the bias measurement methodology and include the bias calculation. A table should be included listing each analyte, with an appropriate range for control limits, acceptable spike and surrogate percent recovery ranges (if appropriate), and performance evaluations and/or confidence intervals for certified reference materials (when appropriate). Also include a table specifying the frequency and type of quality control to be performed with each batch of samples to be analyzed. The table should indicate which analytes will be spiked and which surrogates will be used. Discuss what precautions will be taken to reduce bias due to sample collection procedures (including location and seasonal or other time-related concerns), sample transport, and sample storage (e.g., how will samples be kept cold during and after collection). Other bias sources that should be discussed include: calibrations, reagent quality, method blanks, interference effects, dilutions, and field equipment contamination (equipment rinsate blanks).

- Matrix Spikes and Matrix Spike Duplicates (MS/MSDs) should be performed for all organic compounds on samples from this project. For metals, at least two separate pairs of MS/MSDs per year should be performed on samples specifically from this project. QC should be performed on no less than 10 percent of the analyzed samples. Small batches (less than 20 samples) should include one of each type of quality control (QC) procedure specified.

Contamination in method blank samples will be treated as follows:

- For samples with common contaminants (e.g., lead, zinc), the sample concentration will be at least ten times the blank concentration in order for the result to be considered a valid result.
- For samples with uncommon contaminants, the sample concentration will be at least five times the method blank concentration in order for the result to be considered valid.
- Reporting limits listed in the tables in Appendix C should be met. In some cases, a laboratory may need to focus on reducing laboratory contamination sources to meet the reporting limits.
- Precision: Describe the measurement methodology and include the formula for calculating precision. Include a table indicating the acceptable Percent Relative Standard Deviation (RSD) for laboratory splits, and MS/MSDs. Also, include a table indicating the frequency as well as type of quality control to be performed on each batch of analyzed samples. Laboratory splits (laboratory duplicates), field duplicates (important for sediment and grab samples), and MSDs should be performed with each batch.
- The matrix MS/MSDs for all organic compounds should be performed on samples from this project. For metals, at least 2 separate pairs of MS/MSDs per year should be performed on samples from this project. QC should be performed on no less than 10 percent of the samples being analyzed. Small batches (less than 20 samples) should include one of each type of QC procedure specified.

Full-Scale Laboratory Studies

Except as discussed in the paragraphs below, laboratory testing may precede or augment but cannot entirely replace field testing. Laboratory data are generally useful because data can be generated under controlled conditions, in considerably less time than field tests, and under easily modified design conditions.

Laboratory testing can be conducted to demonstrate TSS removal at peak design flow rates. The vendor should provide detailed test facility descriptions (photos, illustrations, process/flow diagrams), including all relevant factors such as treatment and hydraulic design flow and loading rates on a unit basis (e.g., gallons per minute per square foot), dead storage/detention volumes, inspection protocols to determine when maintenance is needed, maintenance performed during testing, and media type/quantity/thickness.

Laboratory tests should be conducted under the following conditions:

- Constant flow rates of 75, 100, and 125 percent, plus or minus 10 percent, of the manufacturer’s facility design hydraulic loading rate or design hydraulic velocity rate.
- For TSS removal testing, the TSS added to laboratory water should approximate “typical” runoff PSDs for the treatment application (land use). U.S. Silica Sil-Co-Sil 106 ground silica (see Appendix G) can be used to represent a typical PSD. Other materials that more closely simulate “typical” runoff PSD can also be used.
- At a minimum, complete two tests each at 100 and 200 mg/L TSS influent concentration range.

Do not clean filters or settling chambers between tests, unless required under vendor's normal maintenance schedule. Comply with testing and reporting protocols described above. After the TSS tests are completed, test the facility's maximum hydraulic loading rate to check for TSS resuspension and washout (negative removal efficiency). This test shall be conducted with the facility's treatment capability fully utilized (that is, at the time maintenance would be normally be performed, such as when the sediment settling area is full or filter media is saturated). If washout occurs, determine the flow rate where washout begins, and provide for bypassing flows exceeding this flow rate in design guidelines.

Other parameters may also be laboratory-tested. The vendor should consult with the TRC on testing methods prior to initiating work.

LABORATORY QA PROCEDURES

Laboratories performing stormwater sample analysis must be certified by a national or state agency regulating laboratory certification or accreditation programs. For test sites located within Washington State, a Washington-accredited laboratory must complete all laboratory work. The results must be reported in the TEER. Include a table with the following:

- Analyte;
- Sample matrix;
- Laboratory performing the analysis;
- Number of samples;
- Analytical method (include preparation procedures as well as specific methods especially when multiple options are listed in a method); and
- Reporting limits for each given analytical method (include the associated units).

Each laboratory sheet should include the sampling date, the preservation date if applicable, the extraction date, the analysis date, and whether the sample is a QC sample. A table should be provided that shows how laboratory numbers correspond to each site.

When performing composite sampling, the chain-of-custody form will need to include a column for entering the time and date that the first aliquot is collected. The analytical laboratory will need to know this in order to determine when a holding time will be exceeded.

LABORATORY QUALITY CONTROL

In the QC section, describe the laboratory's data quality assurance summary package requirements, including the case narrative. QC samples are used to evaluate data quality. Quality control should describe laboratory control samples, method blanks, matrix spike/matrix spike duplicates (MS/MSDs), duplicates, surrogates, laboratory splits (lab duplicates), and reference samples such as performance evaluations (PE) or certified reference materials (CRM) when applicable.

Provide a table listing all QC samples being performed. Include the number and type of QC analyses that will be performed for each batch of samples. QC should be performed on no less than 10 percent of the samples being analyzed. Small batches should include at least one of each QC procedure specified per batch.

QC results may indicate problems with the data being generated. Additional procedures may be necessary to correct problems. Corrective actions might include re-calibrations, re-analyses of samples, need to re-sample, need for additional samples, qualifying results, etc.

Note: Field QC can include field duplicates, equipment rinsate blanks, and transfer blanks.

DATA MANAGEMENT PROCEDURES

Include a quality assurance summary with a detailed case narrative that discusses problems with the analyses, corrective actions if applicable, deviations from analytical methods, QC results, and a complete definitions list for each qualifier used. Specify field/laboratory electronic data transfer protocols (state the percent of data that will undergo QC review) and describe corrective procedures. Corrections to data entries should include initials of the person making the correction and the date it was corrected. Indicate where and how the data will be stored.

DATA REVIEW, VERIFICATION, AND VALIDATION

Field

Describe procedures for reviewing the collection and handling of the field samples. Establish the approach that will be used to determine whether samples meet all flow sampling and rainfall criteria.

Laboratory

Describe laboratory data review procedures. Validation requires thoroughly examining data quality for errors and omissions. Establish the process for determining whether MQOs have been met. Include a table indicating percent recovery (%R) and relative standard deviation (RSD) for all QC samples. Determine whether precision and bias goals have been met. Establish a procedure to review reporting limits to determine whether non-detected values exceed reporting limit requirements.

Statistical Significance of the Data

Stormwater runoff quality data have been reported to be highly variable (USEPA, 1983-NURP Study, and Strecker, et al, 2001). Therefore, it is necessary to statistically quantify the significance of discrete, paired, and mean pollutant values reported in the TEER. Statistical factors such as confidence levels (up to 95%), calculated p values, power curves, and regression equations should be considered in the statistical analysis. For guidance on the appropriate statistics for this Protocol, refer to Appendix D and other related reports (Pitt, 2002, and Burton and Pitt, 2001).

REPORTING

The sampling results must be presented in the TEER report and include the following:

- Date, time, locations where samples were collected (include a site plan);
- Rainfall data (include antecedent dry period, total rainfall during sampling event, and rainfall duration);
- Comparison of rainfall data to rainfall criteria;
- Comparison of collected aliquots to sampling criteria;
- Comparison of influent to effluent pollutant concentrations;
- Statistical data evaluation;
- Discussion of whether the QAPP objectives were met;
- Discussion on deviations from any sampling procedures;
- Data quality assurance summary package (field and laboratory QA/QC results);

- Maintenance performed during the study period, including:
  - Type of maintenance conducted and frequency;
  - Total amount of sediment and floatables removed and sediment depth prior to each cleaning; and
  - Media replacement and/or cleaning, if applicable.
- Discussion of results; and
- Executive Summary.

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APPENDIX A: TREATMENT EFFICIENCY CALCULATION METHODS

Calculate several efficiencies, as applicable. Consider lag time and steady-state conditions to calculate loads or concentrations of effluents that represent the same hydraulic mass as the influent. State the applicable performance standard on the table or graph.

For technologies sized for long residence times (hours versus minutes), cumulative performance of several storms, wet season or annual time periods must be considered. For short residence times (several minutes), event mean comparisons are recommended and for discrete short-time step residence times (few minutes), lag times should be considered for influent/effluent comparisons.

Method #1: Individual storm reduction in pollutant concentration.

The reduction in pollutant concentration during each individual storm calculated as:

> 100 (flow-weighted influent concentration – flow-weighted effluent concentration)/flow-weighted influent concentration

Method #2: Aggregate pollutant loading reduction.

Calculate the aggregate pollutant loading removal for all storms sampled as follows:

> 100(A-B)/A
>
> Where: A= (Storm 1 Influent concentration) * (Storm 1volume) + (Storm 2 Influent concentration) * (Storm 2volume) +…(Storm N influent concentration) * (Storm Nvolume)
>
> B = (Storm 1 Effluent concentration) * (Storm 1volume) + (Storm 2 effluent concentration) +…(Storm N effluent concentration) * (volume of Storm N)
>
> Concentrations are flow-weighted, and flow = average storm flow or total storm volume (vendor's choice)

Method #3: Individual storm reduction in pollutant loading.

> 100(A-B)/A
>
> Where: A= (Storm 1 Influent concentration) * (Storm 1volume)
>
> B= (Storm 1 Effluent concentration) * (Storm 1volume)

Method #4:

Method #1 applied to partial-storm data (EvTEC approach), comparing influent and effluent discrete flow composites for relatively steady-state flow periods within storms to evaluate removal efficiency versus flow rate. Contact EvTEC at evtec@cerf.org for more information.

If the data allow, show graphically how pollutant removal efficiencies decline from the initial "clean" to ultimate "maintenance needed" condition. This information is useful to assess robustness and to estimate the nature and cost of maintenance.

APPENDIX B: FACTORS OTHER THAN TREATMENT PERFORMANCE

Local government staff should also evaluate relevant factors such as those given below, along with the facility's verified pollutant removal performance. Given the limited experience with emerging technologies, this is an arena where "best professional judgement" based on the "weight of the evidence" is appropriate

The other factors should include the following and should be reported in the TEER:

TECHNOLOGY DESCRIPTION

Describe the treatment technology including process diagrams, primary equipment drawings, sketches, etc. Include details on the relevant treatment mechanisms such as:

Mechanism	Measurement
Anion Exchange (dissolved nutrients)	Each medium's anion exchange capacity.
Cation Exchange(dissolved metals)	Each medium's cation exchange capacity.
Adsorption (dissolved nutrients or metals)	Each target pollutant's adsorption isotherms (capturing typical range of stormwater pollutant concentrations).
Adsorption (hydrocarbons)	Each medium's percent organic matter or organic carbon (mass/mass).
Absorption (hydrocarbons)	Capacity (pollutant mass absorbed per mass and absorbent type).
Vortexing Separation	Flow versus removal efficiency versus grain size and density.
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, provide target pollutant's estimated treatment efficiency versus flow rate.
Settling	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.

APPLICATIONS

- For which applications (e.g., land uses such as roadways, high-use sites, commercial, industrial, residential runoff areas) does the vendor recommend this technology? Why?
- What are the pretreatment requirements?
- Provide a list of the facilities that are installed in the United States. Include addresses and size of each facility. Provide at least three references with names and telephone numbers.

SITE CHARACTERISTICS

Do any of these site characteristics or safety considerations favor or limit the technology's use: climate, rainfall pattern, steep slopes, high groundwater, seepage/baseflows, tidal action, soil type, proximity to wells, septic systems and buildings, facility depth limits for access and safety, hazardous materials spill risk, driving head requirements, and power availability? How?

DESIGN CRITERIA FOR SIZING

- Pollutant removal at design flow and for representative stormwater characteristics;
- Design hydraulics (design flow, by-pass flow, hydraulic grade line, scour velocities, etc.);
- Design residence time, vertical/horizontal velocities, etc.;
- Stormwater constituent limitations (pollutants and other constituents), including fouling factors;
- Specific media flow rate (design velocity);
- Media head loss curves;
- Minimum media contact time and minimum thickness;
- Estimate system/system components design life before major overhaul; and
- Media specifications ensuring adequate media quality at all times. A physical/chemical and impurity specifications list should be provided.

CONSTRUCTION

- What role does the vendor take in design and construction?
- How is the technology installed? How long does it take?
- How are factors such as structural integrity, water tightness, and buoyancy addressed?
- What types of problems can occur/have occurred in designing and installing the technology?
- How are potential problems diagnosed and corrected, and by whom?
- If problems go uncorrected, how does this affect the technology's effectiveness?
- How available is the technology (e.g., where do the major components come from and how much lead time is needed)?

COSTS

- Capital and annual maintenance costs: Base the cost analysis on the test results.
- Indicate approximate annualized system capital/operating costs for all system models on a "design cfs *treated* basis" (not per cfs hydraulic capacity), or a dollar per TSS removed basis, using typical stormwater TSS concentrations (see earlier footnote).
- What is the estimated useful facility life before needing replacement?

OPERATION AND MAINTENANCE

For a typical installation with typical stormwater, discuss each of the following:

- How are inspections performed and how often?
- How do you tell or forecast when maintenance will be needed, i.e., what is the "trigger" for determining maintenance needs and why?
- How is maintenance performed?
- Are all maintenance areas accessible by people and equipment? Are special equipment or methods needed for access? Any confined space entry areas?

- What is the estimated maintenance frequency and on what information/tests do you base this estimated maintenance frequency?
- What maintenance equipment and materials are required?
- Does the vendor offer a maintenance service contract? If so, provide cost information, including mobilization, equipment rental, mileage, solids/spent media disposal, etc?
- How are solids/spent media classified (waste type) and disposed?
- Can the technology be damaged due to delayed maintenance, and if so, how is it restored?
- How many years have you been in business? If vendor goes out of business or product model changes, how/where will facility owner find needed parts, materials, and service?

RELIABILITY

- Assuming the technology is designed and installed correctly, what factors can cause it not to perform as designed?
- Can the technology add, transform, or release accumulated pollutants?
- Does the filter medium decompose or is it subject to slime/bacteria growth?
- Is the technology sensitive to heavy or fine sediment loadings—is pretreatment required?
- How is underperformance diagnosed and treated?
- What is the warranty?
- What initial/ongoing user support is provided? Does the vendor charge for support?

ROBUSTNESS

- How sensitive is the technology's performance to not being maintained correctly?
- How are problems diagnosed and treated?

OTHER FACTORS

Does the technology provide benefits or present challenges in other potentially relevant areas, such as groundwater recharge, thermal effects on surface waters, habitat creation, aesthetics, vectors, safety, community acceptance, recreational use, and efficacy on redevelopment sites?

APPENDIX C: PILOT LEVEL TECHNOLOGIES NOTICE OF INTENT FORM

Treatment Facility Vendor Information

Company:____

Street Address: ____

City: ____________________ State: ____________ Zip Code: ______

Phone/Fax: ____

Email and company web addresses:____________________________

____

Facility name and size:______________________________________

Development level designation sought: ____________________________

Target pollutants: ____

Project Information

Project Name: ____

Street Address: ____

City: ________________

Local Agency with Jurisdiction: ________________________________

Project Type: ____

Desired Installation Date: ________________

Facility Discharge Receiving Water:____________________________

Describe Proposed Testing Plan (e.g., number storms, parameters, test period, who will do work, etc.):

____

____

____

Local Government Certification and Acceptance

Signature: ____ Date: ________________

Name and Title:____

WASHINGTON DEPARTMENT OF ECOLOGY

PILOT LEVEL TECHNOLOGIES NOTICE OF INTENT FORM

Background Information

Local governments with a NPDES permit must submit to Ecology this Notice of Intent Form, and receive Ecology's approval, prior to installing a pilot-designated technology (except in retrofit situations).

It is Ecology's intent that, in all situations where basic or enhanced stormwater treatment is required, that local governments will consider only those emerging technologies that have been tested and evaluated according to the "Guidance for Evaluating Emerging Stormwater Treatment Technologies." However, because local installation and testing are needed in order to obtain performance information, local jurisdictions, industrial/ commercial establishments and consultants are encouraged to pursue limited use of unapproved emerging technologies. When unapproved emerging technologies are to be installed and tested, the responsible party must notify Ecology using this form. **Only technologies that have previously attained "Pilot" designation, and are seeking "General" designation, need complete this form.**

Subject to limitations that Ecology may impose on the number of installations, a vendor of a pilot-designated technology may request local governments to allow limited use of their technology for the *sole* purpose of collecting additional field performance data. Local governments may allow pilot-designated technologies to be installed *only* on less sensitive sites (as defined by the local government), provided that the vendor and/or developer agrees to conduct additional field testing complying with the requirements of the above-referenced document.

Submit completed forms to Ecology, Water Quality Program, P.O. Box 47600, Olympia, WA 98504-7600. Please allow 30 days for response.

APPENDIX D: STATISTICAL CONSIDERATIONS

By Robert Pitt, P.E., Ph.D.

Background

It is important to specify a statistical goal for acceptance or rejection of the evaluation analyses. It is also important that the experimental design consider conservative goals for confidence and power to enable sufficient data to be collected, and that the actual significance level of the results be presented. Stormwater practices that provide relatively low treatment efficiencies are much more difficult to evaluate successfully than more effective controls (if one is trying to show that influent and effluent concentrations are statistically different). However, these less-effective devices may still be used for pretreatment.

Analytical QA/QC procedures theoretically result in very high levels of confidence (at the 99% level), but sampling rarely reaches this pristine level. In characterization studies, it is rare to be able to collect sufficient samples to reduce the errors associated with the median concentrations to less than 25%. A 1% level of error would be unheard of and impossible to obtain. Traditional goals of 95% confidence and 80% power are usually suitable for experimental design, and it is traditional to accept a probability result of 0.05, or less, during analyses for a significant result. It may be suitable and reasonable to accept a level of 0.10 as being significant for many types of tests. The following statistical test probability levels are suggested for different outcomes:

Recommended Statistical Approach

The following statistical approach is recommended:

1. Designs of paired experiments (using local coefficient of variance (COV) values and expected level of control): 90 to 95% confidence (α= 0.05 to 0.1) and 75 to 80% power (β= 0.2 to 0.25).

2. Acceptance levels for statistical tests:

   - Basic treatment (80% TSS reductions): $P \leq 0.05$ that influent does not equal effluent.
   - Enhanced treatment (moderate reductions in dissolved heavy metal concentrations): $P \leq 0.10$ that influent does not equal effluent.
   - Phosphorus treatment (50% reductions in TP): $P \leq 0.10$ that influent does not equal effluent.
   - Oil treatment (no sheen, etc.): $P \leq 0.10$ that influent does not equal effluent.
   - Pretreatment (lesser levels of performance than above): to be considered in conjunction with other treatment train components.

Expected sampling efforts to obtain these above goals are shown on the following table, based on observed Pacific Northwest stormwater monitoring results:

Table 1

Treatment Level	Standard		Minimum Number of Sample Pairs Needed: (confidence/power)		
		COV	**95/80**	**95/50**	**90/80**
Basic Treatment	• 80% reductions for SS	0.55	6	2	5
Enhanced Treatment	• (assume 50% reductions for dissolved heavy metals)	0.50	14	8	10
Phosphorus Treatment	• 50% reductions for phosphorus	0.75	28	15	20

The Experimental Design Process

The following needs to be considered during the experimental design process:

- It may be possible that the COV values for commercial and industrial land uses are higher than in the above calculations, and the corresponding sampling efforts would therefore be greater.
- It is relatively “easy” to measure large differences between influent and effluent conditions, while substantially greater effort is needed when the stormwater control device provides less treatment.
- The sampling effort procedures described in this report are applicable for normally distributed data. If the COV values of the concentrations are relatively low (about 0.4, or less), the corresponding distributions are close to normal distributions. As the COV values increase (as is likely), then greater errors will occur in these estimates. Therefore, these are only guidelines and it is suggested that the actual sampling effort be increased to cover the expected errors. It is also important that the confidence and power levels be calculated for the actual tests, in addition to the measured percentage reductions.
- If the minimum number of sample pairs is used to measure the effectiveness of a control practice for a specific treatment category, the result will basically be a “pass/fail” indication of meeting the treatment goal. If the actual treatment is less than the goal, it is not possible to determine what the actual level of treatment is at the same level of confidence and power. For this reason, it is suggested that the number of sample pairs exceed the minimum number listed for a specific goal category. The following table summarizes the sampling efforts needed (number of tests, or number of pairs of influent and effluent data) for specific treatment goals and COV values, for 95% confidence and 80% power:

Table 2

Performance Level (% reductions)	COV = 0.3	COV = 0.5	COV = 0.75	COV = 1.0	COV = 1.25	COV = 1.50
95 %	<5	<5	8	15	25	30
80	<5	5	12	20	30	45
50	5	13	28	50	80	120
30	12	35	75	130	200	300

The average number of runoff producing rains in the Pacific Northwest is about 100 to 110 per year. If only half of the rains are monitored over an 8 month period, about 35 rains will be sampled. Under this situation, the level of performance that can be statistically established will be limited to:

Table 3

COV	Minimum performance levels that can be statistically quantified for a maximum of 35 paired tests (at 95% confidence and 80% power)
0.3	19 %
0.5	30 %
0.75	45 %
1.0	60 %
1.25	73 %
1.50	90 %

Acceptable Maximum Number of Sampling Events

It may not be possible to measure the performance of marginal stormwater control practices under typical conditions. The 50% performance goal for total phosphorus may be measurable for COV conditions of up to about 0.75, while the 80% basic goal for suspended solids may be measurable for COV conditions of up to about 1.25. These bracket the typical COV conditions for many situations. Again, it is important that the statistical significance of the measured pollutant reductions be reported in all cases (assuming a set level for power). Lower levels of confidence (and power) should be suitable for determining the performance levels of controls if they do not meet the higher performance level goals.

The following is recommended as the maximum level of effort for the evaluation tests:

- The necessary number of sample pairs be calculated based on the local COV for the constituents of interest and using a confidence level of 95% and a power of 80%. (See Figure 2).
- In all cases, at least 12 sample pairs are needed, in order to be reasonably certain of the actual COV and to be able to calculate good statistical relevance values.
- If uncontrollable factors hinder timely conclusions of the sampling effort, or if unusual conditions produce unusually high COV values, then a reasonable maximum sampling effort would be 35 sample pairs.
- In all cases, the statistical outcomes of the analyses need to be specifically noted, not just labeling a test as pass or fail.

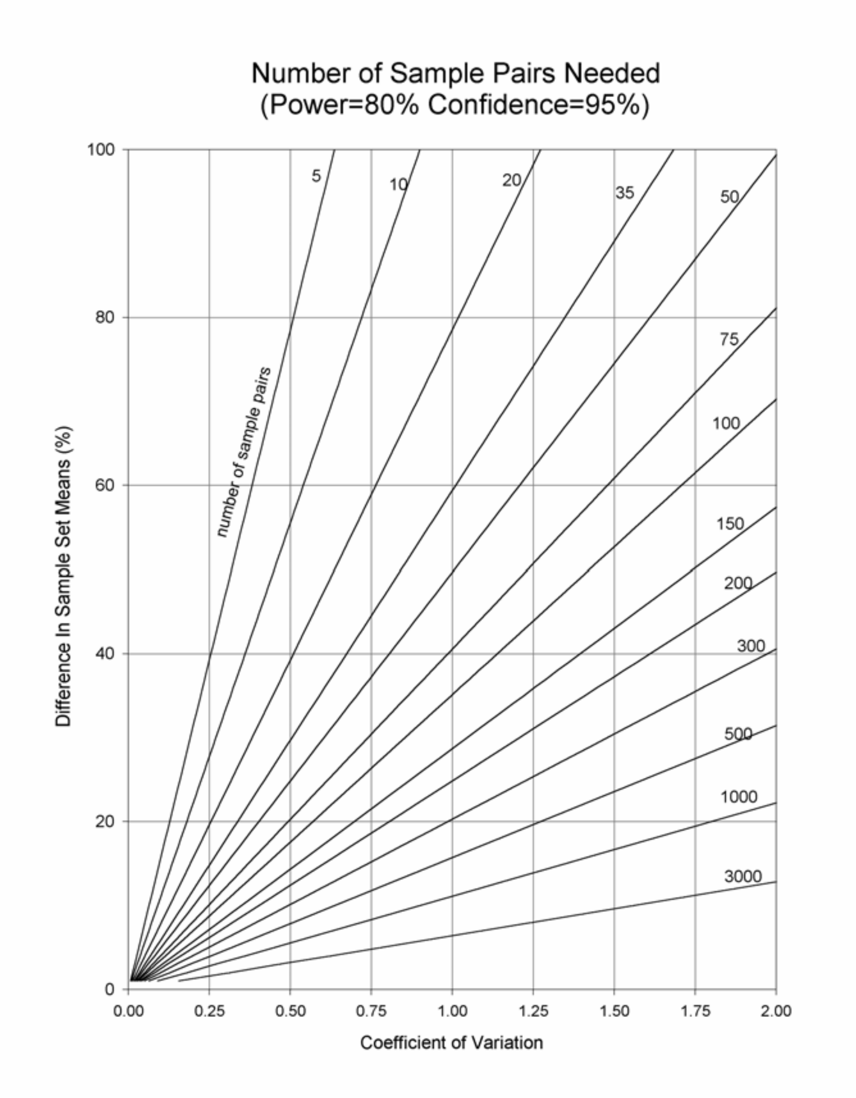

Figure 2. Sample Effort Needed for Paired Testing (Power of 80% and Confidence of 95%) (Pitt and Parmer 1996).

Null Hypothesis- Type I and Type II Errors

The following table describes the relationships between confidence and power, and Type I and Type II errors:

Table 4

	Actual Situation:	
Statistical Decision:	**H_0 True**	**H_0 False**
Do not reject H_0	Confidence ($1-\alpha$)	Type II error (β)
Reject H_0	Type I error (α)	Power ($1-\beta$)

The confidence of a test is to correctly not reject the null hypothesis when it should not be rejected. Another way of stating this Null Hypothesis is "There is a (1-alpha)(100) % confidence that the result represents a true condition." Similarly, the power of a test is to correctly reject the null hypothesis when the null hypothesis is in fact false and should be rejected. The Type I and Type II errors are when the rejection or acceptance actions are not correct. As noted previously, one way to control the probability of making an error is to increase the sample size. For a given level of α, increasing the sample size will decrease β, which increases the power of the test to detect that the null hypothesis is false. However, with any given sample size, increasing confidence necessarily must decrease power. **The only way to increase both objectives is to increase the sample size.**

The experimental designs and associated sampling efforts can be based on these calculations, especially if adjusted upwards to account for deviations in the assumptions. But, nonparametric statistical comparison tests need to be used and the actual test statistics (especially the P values) need to be reported, not just an indication that the null hypothesis was accepted, or rejected. In summary, the following needs to be considered:

- Careful and adequate experimental design must be an integral part of the test procedure in order to be comfortable with both the level of confidence and power of the outcome.
- The statistical tests must report probability of failure (actual calculated p value), not just if "accepted" or "rejected."

DATA EVALUATION METHODOLOGY

The following is a step-by-step procedure for conducting the statistical analysis:

1. Exploratory Data Analysis

In all cases, simple plots need to be presented to observe overall data characteristics. These plots should include probability plots and scatter plots. Grouped notched box and whisker plots are also useful to examine influent and effluent conditions. These plots must be presented along with statistical analyses to quantify the patterns observed.

2. Nonparametric Tests for Paired Data Observations

Nonparametric statistical tests may be a better choice than typical parametric tests. If the data conditions allow parametric tests (at least normally distributed data, for example), then the parametric tests usually have more statistical power. However, few environmental data meet parametric statistical test requirements. If a parametric test is improperly selected, then the calculated results can be very unreliable. **In most cases, nonparametric test alternatives are available and should be used unless the more restrictive test conditions can be met.**

Nonparametric tests also have certain requirements and these need to be considered. Generally, if the COV of a data set is less than about 0.4 (unlikely for most stormwater information, except for pH), it may be possible to use standard parametric tests. Alternately, it may be possible to transform the data (typically by using log transformations) so the data is normally distributed if parametric tests are desired. The following paragraphs summarize some of the more useful nonparametric tests for evaluating stormwater controls.

Nonparametric paired tests are probably the most useful statistical test procedure when conducting stormwater control evaluations. The sign test is the basic nonparametric test for paired data. It is simple to compute and has no requirements pertaining to data distributions. A few “not detected” observations can also be accommodated. Two sets of data are compared. The differences are used to assign a positive sign if the value in one data set is greater than the corresponding value in the other data set, or a negative sign is assigned if the one value is less than the corresponding value in the other data set. The number of positive signs are added and a statistical table is used to determine if the number of positive signs found is unusual for the number of data pairs examined.

The Mann-Whitney signed rank test has more power than the sign test, but it requires that the data distributions be symmetrical (but with no specific distribution type). Without logarithmic, or other appropriate, transformations, this requirement may be difficult to justify for water quality data. This test requires that the differences between the data pairs in the two data sets be calculated and ranked before checking with a special statistical table. In the simplest case for monitoring the effectiveness of treatment alternatives, comparisons can be made of inlet and outlet conditions to determine the level of pollutant removal and the statistical significance of the concentration differences.

Friedman’s test is an extension of the sign test for several related data groups. There are no data distribution requirements and the test can accommodate a moderate number of “non-detectable” values, but no missing values are allowed.

3. Regression Analyses

Regression analyses are very popular, but frequently misused. The use of the regression option in Microsoft Excel provides sufficient information for correct interpretation of the test results. Unfortunately, it is easy to place too much emphasis on the R^2 value when conducting a regression analysis, without first checking on the significance of the equation coefficients, and ensuring that the regression assumptions have been met. An analysis of variance (ANOVA) should always be conducted along with a regression analysis to determine the statistical relevance of the resulting overall regression equation and equation terms. These are always more useful than the traditional R^2 value when determining the acceptability of an equation. It is possible to have a statistically significant and useful model, with a seemingly low R^2 value.

In order to obtain the best and most useful regression analysis results, the following steps were presented by Burton and Pitt (2002):

- Formulate the objectives of the curve-fitting exercise.
- Prepare preliminary examinations of the data (most significantly, prepare scatter plots and probability plots of the data, plus correlation evaluations to examine independence between multiple parameters that may be included in the models)
- Identify alternative models from the literature that have been successfully applied for similar problems.
- Evaluate the data to ensure that regression is applicable and make suitable data transformations.
- Apply regression procedures to the selected alternative models.
- Evaluate the regression results by examining the coefficient of determination (R^2) and the results of the analysis of variance of the model (standard error analyses and p values for individual equation parameters and overall model).
- Conduct an analysis of the residuals (probability plot of residuals, plot of residuals against predicted model outcomes, and a plot of the residuals against the time sequence when the data were obtained). The probability plot should indicate a random distribution of the residuals, while the other plots should indicate an even (and hopefully narrow) band straight across the plot, centered along the 0 residual value. If these plots are incorrect, then the resulting model is likely faulty and should be reconsidered. Data transformations and additional model coefficients are usually used to improve residual behavior).
- Evaluate the results and select the most appropriate model(s).
- If not satisfied, it may be necessary to examine alternative models, especially based on data patterns (through cluster analyses and principal component analyses) and re-examinations and modification of the theoretical basis of existing models.

4. Summary of Results

List all the results based on the exploratory and complete data analyses. Include the statistical determinations for alpha and beta errors, calculated p-values, COV, regression equations and other models plus associated residual analyses, and plot the power curve.

5. Summary of the Statistics Methodology Used

As indicated above, the basic steps in the recommended statistical methodology include:

- Proper and balanced experimental design considering project objectives and expected characteristics
- Conduct initial experiments and initial data evaluations for quality control and general verification of methodology and experimental errors (but don’t make any major changes until sufficient data has been collected and evaluated to protect against premature experimental modifications).
- Conduct complete experiments
- Exploratory data analysis, and other basic statistical tests (comparison tests, regression analyses, etc.)
- Additional statistical tests to investigate other data features (trends, complex interactions, etc.)
- Prepare project report, including recommendations.

APPENDIX E: LABORATORY METHODS

Table C-1: Recommended Analytical Procedures in Stormwater.

Parameter	Analyte (or surrogate)	Method (in water)	Reporting Limit[b,c]
Conventional Parameters	Total suspended solids	EPA Method 160.2 or SM 2540[d]	1.0 mg/L
	Total dissolved solids	EPA Method 160.1 or SM 2540C	1.0 mg/L
	Settleable solids	EPA Method 160.5 or SM 2540F	1.0 mg/L
	Particle size distribution	Coulter Counter or Laser diffraction, or comparable method	
	Grain-size	Ecology method sieve and pipette (PSEP 1997), or comparable method	
	pH	EPA Method 150.1 or SM 4500H$^+$	0.2 units
	Hardness as $CaCO_3$	SM 2340B (ICP) or 2340C (Titration)	1.0 mg/L
Nutrients	Total phosphorus	EPA Method 365.3 or SM 4500-P I	0.01 mg P/L
	Orthophosphate	EPA Method 365.3 or SM 4500-P G	0.01 mg P/L
	Total kjeldahl nitrogen	EPA Method 351.2	0.5 mg/L
	Nitrate-Nitrite	EPA Method 353.2 or SM 4500 -$NO3^-$ I	0.01 mg/L
Metals	Total recoverable zinc	EPA Method 200.8 (ICP/MS) or 200.9 (GFAA), or SM 3125 (ICP/MS)	1.0 ug/L
	Dissolved zinc[a]	EPA Method 200.8 (ICP/MS) or 200.9 (GFAA), or SM 3125 (ICP/MS)	1.0 ug/L
	Total recoverable zinc	EPA Method 200.7 (ICP) or SM 3120	5.0 ug/L
	Dissolved zinc[a]	EPA Method 200.7 (ICP) or SM 3120	5.0 ug/L
	Total recoverable lead	EPA Method 200.8 (ICP/MS) or 200.9 (GFAA), or SM 3125 (ICP/MS)	2.0 ug/L
	Dissolved lead[a]	EPA Method 200.8 (ICP/MS) or 200.9 (GFAA), or SM 3125 (ICP/MS)	2.0 ug/L
	Total recoverable copper	EPA Method 200.8 (ICP/MS) or 200.9 (GFAA), or SM 3125 (ICP/MS)	2.0 ug/L
	Dissolved copper[a]	EPA Method 200.8 (ICP/MS) or 200.9 (GFAA), or SM 3125 (ICP/MS)	2.0 ug/L
	Total recoverable cadmium	EPA Method 200.8 (ICP/MS) or 200.9 (GFAA), or SM 3125 (ICP/MS)	0.2 ug/L
	Dissolved cadmium[a]	EPA Method 200.8 (ICP/MS) or 200.9 (GFAA), or SM 3125 (ICP/MS)	0.2 ug/L
Petroleum Hydrocarbons	NWTPH-Dx	Ecology, 1997, (Publication No. 97-602) or EPA SW-846 method 8015B	0.25-0.50 mg/L
	NWTPH-Gx	Ecology, 1997, (Publication No. 97-602)	0.25 mg/L
Toxicity	*Daphnia pulex*	EPA Method 600/4-90/027F (acute)	NA
	Ceriodaphnia dubia	EPA Method 600/4-90/027F (acute)	NA

a. Dissolved metals analysis is required only if vendor claims the technology will remove the dissolved species/fractions
b. Reporting Limits established as per Manchester Environmental Laboratory Users Manual (Ecology, 2000)
c. All results below reporting limits should also be reported and identified as such. These results may be used in the statistical evaluations.
d. To ensure accurate results, Ecology recommends modifying these methods to analyze (filter) the entire field sample. Research results indicate that errors may be introduced by decanting a subsample, although using a funnel splitter may help. The analyst may also consider analyzing several premixed subsamples from the same sample container to determine if significant variability occurred due to stratification. The QAPP and TEER shall indicate whether the entire field sample or a subsample is used.

NA – Not applicable

SM – Standard Methods

Table C-2: Recommended Analytical Procedures in Sediment.

Parameter	Analyte (or surrogate)	Method (in Sediment)	Reporting Limit[b, c]
Grain-size	Total Solids TVS Grain-size	EPA Method 160.3 or SM 2540B EPA Method 160.4 or SM 2540E Ecology Method Sieve and Pipet (PSEP 1997) or ASTM F312-97	NA 0.1%
Metals[a]	Total Recoverable Zinc	EPA Method 200.8 (ICP/MS) or SM 3125 (ICP/MS) EPA Method 200.7 (ICP)	1.0 mg/Kg 0.4 mg/Kg
	Total Recoverable Lead	EPA Method 200.8 (ICP/MS) or SM 3125 (ICP/MS) EPA Method 200.9 (GFAA)	0.1 mg/Kg 0.2 mg/Kg
	Total Recoverable Copper	EPA Method 200.8 (ICP/MS) or SM 3125 (ICP/MS) EPA Method 200.9 (GFAA)	0.1 mg/Kg 0.2 mg/Kg
	Total Recoverable Cadmium	EPA Method 200.8 (ICP/MS) or SM 3125 (ICP/MS) EPA Method 200.9 (GFAA)	0.1 mg/Kg 0.02 mg/Kg
Petroleum Hydrocarbons	NWTPH-Dx	Ecology, 1997 (Publication No. 97-602) or EPA SW-846 method 8015B	25.0-100.0 mg/Kg
Toxicity	*Daphnia pulex* *Ceriodaphnia dubia*		

(Note: The ASTM methods for WET should be kept as is)

a. Dissolved metals analysis is required only if vendor claims the technology will remove the dissolved species/fractions
b. Reporting Limits established as per Manchester Environmental Laboratory Users Manual (Ecology, 2000)
c. All results below reporting limits shall also be reported and identified as such. These results may be used in the statistical evaluations.
NA – Not applicable
SM – Standard Methods

APPENDIX F: PARTICLE SIZE DISTRIBUTION

Wet Sieve Protocol and Mass Measurement

(Recommended by the TRC Subcommittee)

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 since 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 um. Therefore, particles greater than 250 um 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 um. 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 um in order to be consistent with the Guidance for Evaluating Emerging Stormwater Treatment Technologies definition of TSS (total suspended particles <500 um).

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 degrees 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 (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. It is recommended that this request also 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 Liters of stormwater sample water (total sample required for analysis (ASTM D 3977))
__ Drying oven (90 degrees 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 um (Tyler 32, US Standard 35)
    __ 250 um (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 um and 500 um 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 um 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 um) will not be analyzed with the laser diffraction PSD.
- Dry each sieve (500 um and 250 um) 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 ($\geq$ 500 um and 499 - 250 um).
- Document the dominant types of particles/debris found in this each size fraction.

Laser Diffraction (PSD)

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

Mass Measurement

Equipment

__ Glass filter - 0.45 um (pore size) glass fiber filter disk (Standard Method D 3977)
(larger diameter sized filter is preferable)
__ Drying oven (90 degrees 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 um 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 um 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 um 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 um) is composed primarily of beauty bark, or cigarette butts, or other organic debris this should be noted. An option might also be for a geology expert 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.

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 G: SIL-CO-SIL 106 PRODUCT DATA FROM U.S. SILICA

Sil-Co-Sil 106 is a readily available ground silica product, manufactured by U.S. Silica Corporation. It retails for about $100 per ton in 50 pound bags, plus shipping costs. Information on this product is available at:

http://www.u-s-silica.com/prod_info/PDS/Mill_Creek/MiCSCS1062000.PDF

This product has the following particle size distribution:

Less than 150 microns, 99.9%
Less than 106 microns, 98%
Less than 75 microns, 93%
Less than 50 microns, 80%
Less than 10 microns, 30%

Mean particle size 19 microns. Single grain, specific gravity 2.65.

Local Distributor:

Ted Garrett
J.F. Shelton Co.
Kent, WA
(253) 872-6363

Small quantities of 50-pound bags would require special arrangements.