ASCE GUIDELINE FOR MONITORING STORMWATER GROSS POLLUTANTS

Written by the
Environmental Water Resources Institute
Urban Water Resources Research Council
Gross Solids Technical Committee

Editors
Betty Rushton Ph.D., University of Florida, Gainsville
Gordon England P.E., Stormwater Solutions, Inc., Cocoa Beach
Daniel Smith Ph.D, P.E., Applied Environmental Technology, Thonotossa

Contributors

Contributors:
John Gray
Guo Qizhong
Roger James
Linda Pechacek
Robert Pitt
Marcus Quigley
John Sansalone
William Selbig
Ben Urbonas
Tony Wong

ABSTRACT

Gross pollutants have not usually been considered in monitoring studies that have quantified pollutant removal efficiency for stormwater Best Management Practices (BMPs). Gross pollutants generally consist of litter, debris, and coarse sediments. While these pollutants are not normally monitored in testing programs, many other pollutants of concern are bound to the gross pollutants. As a result, these pollutants degrade aquatic habitat, cause visual blight, smother productive sediments, leach harmful pollutants, and can cause unpleasant odors.

In response to growing concerns about gross pollutants in urban areas, manufacturers have developed a number of proprietary products designed to trap and separate this trash from the runoff flow path before discharge. Most of these BMPs are still in their early implementation stages and have not been fully tested in the field. Therefore, removal efficiencies are often based on tests of scaled models in the laboratory. In addition, most gross pollutants cannot be sampled by traditional automatic samplers and have been ignored in studies evaluating the impact of stormwater runoff on receiving waters.

In order to address this issue, ASCE's Urban Water Resources Research Council has

written a standardized protocol for measuring gross solids. This protocol establishes a standard for testing end of pipe BMPs, inlet traps, and other BMPs which collect gross pollutants.

INTRODUCTION

Gross solids are the litter, trash, leaves and coarse sediments that travel either as floating debris or as bed loads in urban runoff conveyance systems. In the past, most monitoring programs designed to determine the effectiveness of Best Management Practices (BMPs) for stormwater pollution have narrowly defined the size, concentration, and mass of *solids* in the runoff. This is attributed to the sample collection method commonly used. These methods generally exclude *solid material* greater than 75 microns that is not effectively collected using automatic water quality samplers, as well as coarse sediments that are transported as bed-loads. Though often unaccounted for in monitoring programs, these large size pollutants degrade aquatic habitat, cause visual blight, smother productive sediments, leach harmful pollutants, and can cause unpleasant odors.

Historically, evaluations of stormwater Best Management Practices, (BMPs), have focused on dissolved and suspended pollutants in the water column because the sampling methods were adapted from people's experience with wastewater treatment plants. Therefore, pollutants were sampled in the influent and effluent water using grab samples from the water column or autosamplers, and flow measurements were made using velocity or weir measurements. Stormwater pollutants differ from wastewater, however, by being intermittent in nature and often having high volumes of gross solids in the storm runoff that are not measured using autosamplers or other standard techniques. This committee recommends guidelines for measuring the gross pollutant fractions found in stormwater.

Gross solids are broken into 3 categories:

1. **Litter** includes human derived trash, such as paper, plastic, Styrofoam, metal and glass greater than 4750 µm in size.
2. **Organic Debris** consists of material including leaves, branches, seeds, twigs and grass clippings greater than 4750 µm in size.
3. **Coarse sediments** are inorganic breakdown products from soils, pavement, or building materials greater than 75 microns. It also includes fragments of litter and organic debris not included in the other two categories.

The selection of 75 microns as the lower size limit used in the definition of gross solids was chosen because this is usually the largest size that can be collected using autosamplers and about the smallest size collected by proprietary units designed to collect gross solids. A lower limit of 75 microns was also selected since this is the boundary between sand and silt used by soil scientists and it is easily separated in the laboratory using a #200 U.S. sieve size.

Litter has been reported in the literature using a wide range of sizes as the lower limit (5 to 10 mm). These have usually been selected to match the size of the mesh in the type of device used to collect the litter. In this guideline, the boundary of 4.75 mm was selected as the lower limit for litter and organic debris since it would be impossible to separate small fragmented particles from the coarse sediment size fraction. In addition, this size can be conveniently separated in the laboratory using a #4 U.S. sieve size and includes the 5 to 10 mm size reported by other studies. A laboratory test can be used to quantify the organic fraction of the less than 4750 µm solids and distinguish the organic fraction from the coarse sediment, if this is one of the goals of the monitoring project.

A gross solid monitoring guideline is needed for several reasons:

- The U.S. Environmental Protection Agency identified sediment as the most widespread pollutant in the Nation's rivers and streams, affecting aquatic habitat, drinking water treatment processes, and recreational uses of rivers, lakes and estuaries (US EPA 2000).
- The growing interest in mitigating the aesthetic and environmental impacts of trash and debris in the nation's waters and regulation of these pollutants through TMDLs has resulted in the development of a number of proprietary products designed to trap and separate large particles from the runoff flow path before discharge. The performance of treatment devices and the material collected by these devices have not been fully tested with standard methods and cannot be evaluated using past techniques.
- An accurate quantification and characterization of gross pollutants is needed for selecting the proper BMP design to capture gross solids and to determine maintenance requirements and schedules.
- Most gross solids cannot be sampled by traditional automatic samplers and have been ignored in studies evaluating the impact of storm water runoff on receiving waters.
- Some research is reporting that a significant portion of the mass of heavy metals, PAHs, and nutrients such as total phosphorous are associated with particles >150 µm that have not been effectively sampled in the past (Sansalone et al. 1998, Rushton 2006).

The purpose of this guideline is to standardize data collection procedures used in evaluating the removal of Gross Solids by BMPs and also to allow for direct comparison of field data from separate studies by using the same collection methodologies. Since the protocol for collecting and analyzing pollutants in the water column is well represented elsewhere, (i.e. TARP 2003, ASCE/EPA 2002, EPA 2002), these practices will only be mentioned in passing; while the guidelines presented in this report will emphasize methods for evaluating Gross Solids.

BACKGROUND

The total pollutant load entering a BMP is a combination of pollutants suspended and dissolved in the water column, as well as pollutants associated with the Gross Solids, which may be floating litter and debris, large organic and inorganic materials suspended in the water column, or bed-loads rolling along the bottom of the conveyance system. A conceptual framework of the various phases of constituents in stormwater is shown in Figure 1. Solids in stormwater consist of dissolved molecules, colloids, and suspended particles, as well as larger sized floating or suspended matter. The smallest particles, colloids, are present in large concentrations in natural water and their large surface area provide numerous adsorption sites for pollutants (Minton 2005), but larger often heterogeneous particles also provide numerous adsorption sites. Large particles are rarely smooth or spherical in shape and scanning electron microscopy readily reveals that these highly irregular shapes greatly increase their surface area. In a detailed study of highway runoff, particles in the 420 to 850 micron range had the highest total surface area for all storm events measured (Sansalone *et al*. 1998). These folds, pores, notches, pits and roughness result in additional surface area which increases the opportunity for attachment sites and chemical reactions.

In addition, it is important for the stormwater manager to understand the types of particles in stormwater in order to apply appropriate treatment techniques to control pollution. Different type systems are more efficient for removing certain particle sizes. Also understanding the relative position in the watershed of the treatment system can make the best use of limited resources. For example, large particles (gross solids) are discharged near source areas while smaller particles are more readily transported in the flow stream. An understanding of particles also takes into consideration that large particles tend to clog the filter systems that are more efficient for removing small suspended solids, colloidal and dissolved constituents. The implication here is that some kind of pre-treatment should be employed before stormwater enters systems that use filtration for removing smaller particles.

It should be remembered that chemical reactions are constantly taking place between constituents in all particle size classes. These are controlled by conditions in the water column, such as temperature, pH, dissolved oxygen, and alkalinity. In addition, physical conditions including parameters such as position in the watershed, flow characteristics, storm intensity, turbulence, hydraulic efficiency, first flush phenomenon, and friction also affect the size of particles and constituent fractionations that are shown in Figure 1. Colloids, dissolved and suspended solids have been well studied in stormwater research projects since they are routinely collected by using automated water quality samplers. Even much of the settleable fraction, which is defined as material that falls to the bottom of an Imhoff Cone in one hour, is usually included in the water sample.

Measuring only the water column solids has led to the misleading conclusion that most pollutants in stormwater are primarily suspended. In many cases the settleable suspended solids have fallen out in the upstream collection system of pipes and swales and are underrepresented or not collected at all in water column samples. Floating litter and debris are not collected by water column samplers with intake pipes located below the surface, or are removed by strainers. In contrast, studies that capture the entire cross-section of flow or take samples close to the location of solids entrainment have shown that the majority of the original particle mass in urban rainfall-runoff are actually in the settleable-sediment range (>250 um)(Sansalone *et al*. 1998, Sansalone *et al*. 2005). Proprietary devices such as hydrodynamic separators and baffle boxes primarily capture only this large size fraction. However, including these coarse sediments, organic debris and trash in this larger size fraction increases the complexity in calculating a removal efficiency of solids and other pollutants.

The division between suspended and settleable particle sizes uses the 1-hr Imhoff settling test. The division between settleable and sediment is the fraction that passes through a #200 U.S. size sieve. Figure 1 is based on work done by Dr. John Sansalone.

METHODS

Calculation of BMP removal efficiencies for Gross Solids is not as straight forward as the removal efficiency calculations for dissolved and suspended pollutants in the water column because any upstream sampling for Gross Solids will reduce the mass trapped in the BMP, affecting the mass of the Gross Solids removed and the removal efficiency calculation**.** For dissolved and suspended solids, flow weighted, well mixed sub-samples are taken in the water column upstream and downstream of a BMP and a concentration and mass comparison is easily made. **The nature of Gross Solids is such that at this point in time there are no proven methods for comparing upstream and downstream loadings since Gross Solids are measured as a total mass rather than a concentration.** The reason for the difficulty in finding a convenient method of combining gross solids and suspended solids is a difference in measurement techniques. For example, a common pollutant in stormwater flow is suspended sediment, measured as concentrations with units in milligrams per liter (mg/l), and reported as total suspended solids (TSS), or less often as suspended sediment concentration (SSC). It is more common for proprietary BMPs such as hydrodynamic separators and inlet traps to collect Gross Solids greater than 75 microns in diameter; and mass based estimates must be used for net solids captured in these devices. These are typically calculated from the mass of solids and the specific pollutant concentration within that solid mass in mg/kg.

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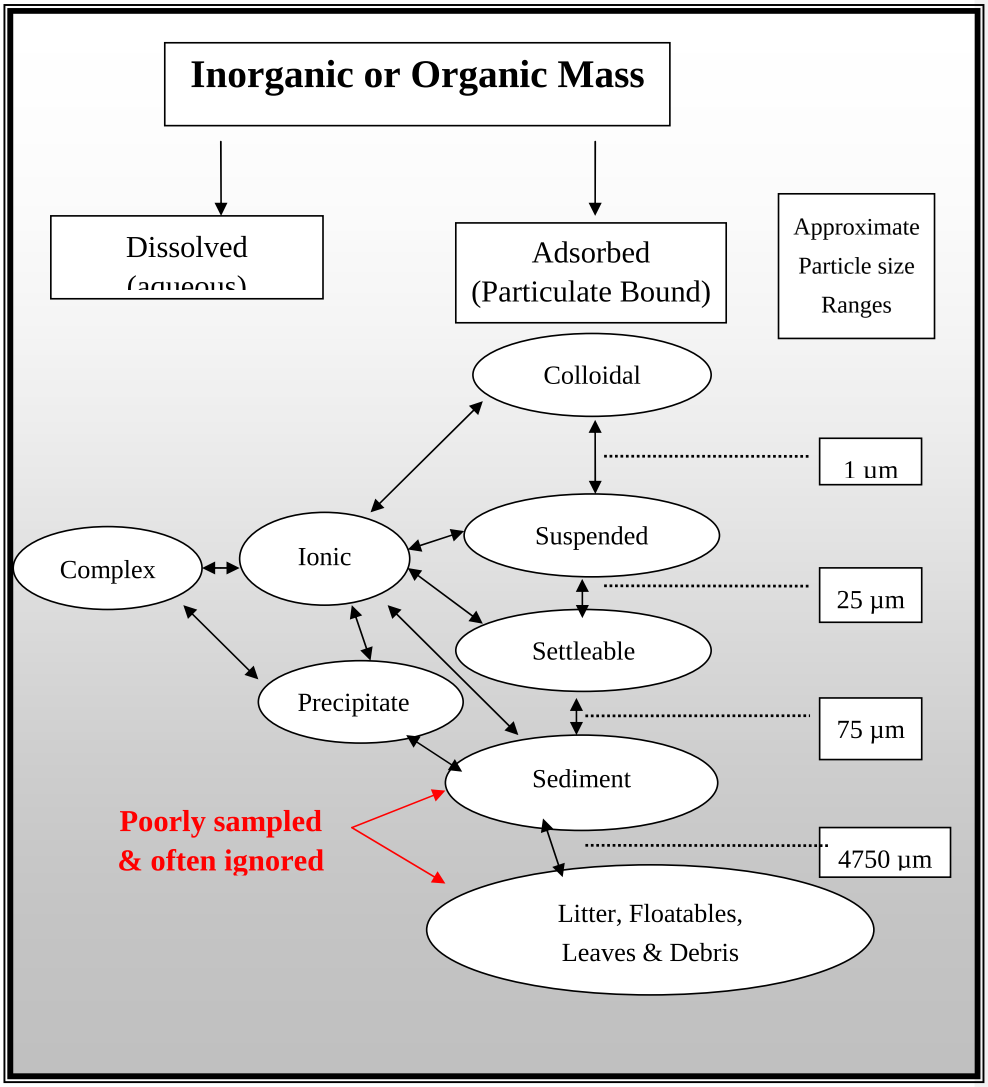
At the present time, an estimate of overall efficiency for a stormwater BMP that includes both water column and gross pollutants must combine measures of efficiency for the water column based on flow volume and flow weighted composite samples with estimates of mass removal of gross solids that are normalized back to the total stormwater volume for an event of time period. T**here is no appropriate "conversion factor" for combining TSS or other stormwater pollutants in the water column with the gross sediment mass in order to calculate overall removal efficiencies.** Since the volume and mass of gross pollutants captured in a BMP are the only data that can be measured, this guideline focuses on methods to quantify the volume and mass of gross pollutants captured.

One of the major differences between gross pollutant traps is that some devices are designed to retain the collected material in a wet sump until the unit is cleaned out (wet systems) while in other designs the collected material remains above any standing water in the BMP, (dry systems). Quantification of the amount of gross pollutants collected in wet units is not a simple task since (1) it is difficult to obtain an accurate dry weight of collected material, (2) the decanted water may dissolve or mask gross pollutants, and (3) some of the pollutants leach out of the gross pollutants into the standing water in relatively short time periods (Strynchuk *et al*. 2000). In addition, even when pollutants, such as heavy metals associated with gross solids are not immediately bioavailable they may later accumulate in the sediments and become highly toxic when metabolized by benthic organisms (Burton and Pitt 2002).

Figure 1

Conceptual Framework of Particle Size Distribution and Partitioning in Stormwater Runoff.



In contrast, dry systems, such as inlet traps, make characterization and testing of gross pollutants a somewhat simpler and more accurate process than wet BMPs. In dry systems, it may be possible to collect nearly 100% of the pollutants in the screens or filters. Where appropriate in this guideline, a distinction is made for methods that are necessary for wet verses dry systems. For information purposes, Appendix A provides a list, brief summary and some web addresses of various types of gross solid collection devices.

MONITORING PLAN DEVELOPMENT

In order for a monitoring program to deliver a reasonable level of accuracy, the program must be well planned. There are large variations in pollutants accumulated in BMPs between rainfall events. These are due to many variables, such as size of contributing watershed, rainfall intensity and duration, antecedent dry period, land use, soil type, seasonality, deicing practices, etc. These variations are even more significant for Gross Solids than suspended or dissolved water column constituents. In order to normalize these variations, yearly data accumulation measurements of gross pollutants will provide more useful results than shorter time frequency comparisons. It therefore becomes important to keep accurate records of cleanout intervals, cleanout volume, and cleanout mass. In addition, drainage basin and weather characteristics should be collected, such as rainfall amount, intensity and duration, number of rainfall events, drainage basin size, land use, types of curbs on streets, other BMPs in the basin, any street sweeping activities, unusual weather events, and proximity to major pollution sources such as beaches or industries. The basic information collected should be consistent with the National Stormwater BMP Database Requirements.

PROGRAM LEVEL DETERMINATION

The first step in any monitoring plan is to determine the purpose and budget available for the monitoring. A monitoring program can range from basic and relatively inexpensive, to extremely complex and expensive. Recognizing that not all BMP monitoring programs have the same goals or funding levels, three levels of monitoring are defined to balance goals, funding constraints, and levels of accuracy.

Level 1 - A Level 1 monitoring program requires a basic data gathering effort to provide minimal BMP performance data by quantifying the mass or volume of the gross solids removed and by analyzing a limited number of pollutants in the solids. It is not necessary to include water column monitoring, although this could provide useful information. Examples of Level 1 programs are the requirements associated with State or Federal grants to communities for stormwater retrofitting projects. Grant conditions often require that a small number of parameters be tested, which will provide performance data to determine the effectiveness of a BMP installed with grant funding. The objective is to demonstrate pollution removal for the BMP based upon the pollutants collected. In order to control costs, minimal laboratory analysis is performed and statistical validity of results using a large number of storms is not typically required. At least two gross solid samples would be analyzed for each cleanout period for Level 1. Each succeeding program level should include all of the elements of the preceding level.

Level 2 - Level 2 programs are of a higher level of complexity and cost than Level 1 programs, and include water quality sampling and collection of flow data, as well as analysis of gross solids. Extensive laboratory tests are used to quantify individual pollutants of concern. These programs could be used by BMP developers or agencies for screening performances of BMPs, or for studies to set TMDL regulations. In addition to gross solids samples, water column samples are required. An example of the water column sampling and analysis component of a Level 2 testing program is published in the Technology Acceptance Reciprocity Partnership Protocol for Stormwater Best Management Practice Demonstrations (TARP 2003), endorsed by California, Massachusetts, Maryland, New Jersey, Pennsylvania, and Virginia. For the TARP protocol, a minimum of 10 storm events greater than 0.1 inch of rainfall are tested using flow weighted composite samples from autosamplers. Accurate flow measurements are required to determine flow rates and volumes for each storm. Long term sampling of at least one year is recommended to account for seasonality of pollutant loadings and rainfalls. The TARP program and others of this type only measure water column pollutants in dissolved and suspended forms. The sampling scheme proposed in this Guideline for Monitoring Gross Solids should be added to the TARP-type program to produce a Level 2 monitoring effort.

Level 3 - Level 3 programs are highly complex, and often expensive studies of BMPs that could be used to develop new or improved BMPs, and to perform multi-year analysis of annual mass loadings, long term impacts on ecosystems, or TMDL development. These programs are customized to study many parameters, or specific parameter(s), such as toxic organics. These studies are typically performed by technology testing and development firms or universities and the research scientist or engineers determine the parameters to be measured.

QUALITY ASSURANCE PLAN

The next step is to develop and obtain approval of the appropriate Quality Assurance Project Plan (QAPP) required by local or state authorities. A QAPP plan establishes the test methods, equipment, and procedures that should be used to collect stormwater BMP data. Test results will not be recognized by authorities without an approved QAPP plan.

GROSS SOLIDS SAMPLING

MASS REMOVAL

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The first step in taking samples is to determine the volume and mass of each of the different categories (litter, debris, or sediment) sampled. With dry systems, 100% of the volume and mass of Gross Solids can generally be collected and measured inside or outside of the BMP. If the Gross Solids are damp it will be necessary to dry the debris to calculate a dry density. Floating debris and litter should be separated from the total mass and measured separately.

Organic debris from decomposing leaves and grass sometimes dissolves to become very small particles which are difficult to discern from coarse sediment. Some pollutants attach to the organic debris in different concentrations than found on coarse sediments. With each increase in program level there will be an increased effort and expense to more accurately separate the organic particles from coarse sediment and determine the associated pollutants of each.

Level 1 – Depth measurements should be taken at enough locations in the unit to determine the average depth for volume calculations. Additional measurements should be taken if the accumulated mass is unevenly distributed in the bottom of the BMP. To calculate mass from volume measurements, representative samples should be taken, composited, and analyzed for a single density determination and analyzed for pollutants of concern. In some applications it may be difficult to accurately measure depth of the accumulated mass while it is still in the unit and the gross pollutant mass may have to be estimated at the disposal site.

Level 2 – At this Level the debris and sediment will be further separated and the volume and mass of each calculated. There will be different degrees of effort and different methods required to collect and separate samples in dry verses wet systems. If appropriate, sediment, grass, and organic debris should be washed from floatables and returned to the BMP. An attempt should be made to separate organic debris from sediment, although this will not be completely possible with fine debris. A discussion of sediment collection is given in the Sediment section below. An estimate of the trapped liquid volume should be made, samples of this volume taken, and water quality tests made for traditional pollutants of concern. Using the concentrations from the water quality tests and the volume of liquid in the BMP, masses of the pollutants of concern should be calculated and added to the total mass accumulations.

LITTER

Dry BMPs

Most dry BMPs are inlet traps. There may also be a vault type sediment sump with a screen attachment that keeps the debris dry to prevent nutrients in the organic debris from leaching into the sump. This type of BMP is a combination wet and dry BMP.

Level 1 and 2 – When BMPs are used with grated inlets, most of the litter is trapped by the grate and does not enter the BMP. If the stormwater runoff is being characterized, the litter trapped on the grated inlet should be gathered, separated, dried, and measured for volume and weight. If only the removal efficiency of the inlet trap is being determined, litter within the inlet trap should be collected. With BMPs in curb opening inlets, the accumulated floating litter falling into the BMP should have volume and weight measurements taken.

Level 3 – For specialized studies, the litter might be further subdivided into desired categories and measured for volume, and/or mass, and/or other desired numbers. See Appendix A for an example of litter classification from New York City.

Wet BMPs

Level 1 and 2 – Calculate an estimate of the volume of litter. It is preferable to estimate the volume while it is still in the BMP, but logistics may make it necessary to separate and measure the volume when it is dumped at the disposal site.

Level 3 – For specialized studies, the litter might be further subdivided into desired categories and measured for volume, and/or mass, and/or other desired categories.

DEBRIS

Dry BMPs

Level 1 – Debris within the inlet trap should be collected, if possible and volume and weight measurements taken or estimated by visual inspection and subsamples weighed. A representative sample of the organic debris/sediment mixture should be tested for Total Volatile Solids (TVS), which determines the organic content of a debris/sediment sample.

Level 2 – Dissolved debris can be difficult to separate from sediment. At this level more effort to separate debris from sediment should be taken by using Differential Thermal Analysis (DTA). Since organic content can vary depending on the temperature used in the DTA analysis, four aliquots of sediment/debris mixture should be taken and burned at 104°, 150º, 300º, and 550º Fahrenheit. A mean value should be calculated from the four samples. A representative sample of organic debris should be tested for total nitrogen, total phosphorus, TKN, BOD, COD, pesticides, mercury, individual PAHs, and pollutants of special concern.

Level 3 – For specialized studies, tests for other constituents in the debris can also be made.

Wet BMPs

Level 1 – Calculate an estimate of the volume of debris. It is preferable to estimate the volumes while they are still in the BMP, but logistics may make it necessary to measure volumes when they are dumped at the disposal site. A representative sample of the combined sediment and debris should be tested for TVS and other pollutants of concern.

Level 2 – Debris should be removed, sorted, and weighed separately. For the mixture of debris and sediment of the BMP, representative samples of material should be taken in a manner which gives an estimate of the % Organic Matter in the mixture. A wet density of the debris and sediment mixture should be calculated. The volume of debris and sediment should be estimated separately and masses calculated. The volume and mass of floating debris and litter should be added to the volume and mass of litter and debris in the bottom of the BMP to give a total mass and volume of litter and debris. In a representative sample, the debris and sediment should be separated and each tested for TVS, total nitrogen, total phosphorus, TKN, BOD, COD, pesticides, mercury, and individual PAHs.

Level 3 **–** For specialized studies, tests for other constituents may also be made.

SEDIMENT

Level 1 **–** For a basic Level 1 program, measure the total mass of mixed debris/sediment captured in each chamber of a wet or dry BMP using the techniques discussed above. A representative sample of the mixed sediment/debris should be tested for TVS and pollutants of special concern.

Level 2 **–** For this Level, a representative sample of mixed debris/sediment in each chamber should be taken. Wash any sediment from floating litter and debris and add the washed sediment to the total sediment mass. It may be desirable to composite a sample from all chambers for testing to determine disposal restrictions using a Toxicity Characteristics Leachate Procedure (TCLP). Next, dry the samples, and separate the organic debris from the sediment as discussed above. Representative samples of the separated sediment and debris should each be analyzed independently for TVS, total nitrogen, total phosphorus, TKN, BOD, COD, pesticides, mercury, total copper, total lead, total zinc, and individual PAHs. If it is not possible to separate the organic material from the sediments, ash tests might be performed on washed and unwashed samples to quantify sediments.

Level 3 **–** In this research Level a detailed analysis of the debris and sediment captured will be performed by taking multiple samples for statistical validity
Note that the chemical analysis for the gross pollutants may cover different parameters than the water quality testing regime since some parameters, such as PAHs, can be tested in sediment but not in water with autosamplers, or dry sediment can not be tested for TSS.

Certain BMPs have combination wet and dry designs. Monitoring of gross pollutants for these devices will require customized approaches. The plan for testing these BMPs should be designed using the appropriate combinations of the above procedures.

SUMMARY

Testing gross solids in stormwater BMPs can be more difficult and expensive than traditional water quality testing, often requiring more sample handling and preparation, lab work, personnel time, and expense. There are many types of vendor products being developed to remove gross solids, and each one will require its own customized monitoring program to match the unique characteristics of the BMP, but certain standardized methods need to be included.

To determine the total pollutant load removed in a BMP, the dissolved and suspended solid mass should be calculated using traditional auto-sampling techniques, flow composite sampling and analyses. Water column mass should then be combined with the mass of Gross Solids, Gross Solids-associated pollutants, and non-solids associated pollutants within the BMP to give a total pollutant mass removed. It is straightforward to calculate removal efficiencies for dissolved and suspended solids, but methods for calculating removal efficiencies under field conditions for Gross Solids are currently under development.

Table 1
Program Level Summary

Level 1 **Minimal Monitoring**	**Level 2** Detailed Monitoring	**Level 3** **Research and Design**
1. Rainfall 2. Time interval since last cleaning 3. Volume and weight of material captured in each chamber 4. Separation of large litter from coarse sediment and organic debris 5.Two chemical analyses of sediment/debris mixture 6.Percent Organic Matter of sediment/debris sample 7. Percent Solids	1. Separation of organic debris from coarse sediment 2. Mass and weight of debris 3. Mass and weight of sediment 4. Sediment particle size distribution using sieve analysis 5. Chemical analysis for two debris sample per chamber 6. Chemical analysis for two sediment sample per chamber 7. Percent Organic Matter of sediment sample in each chamber 8. Water Quality sampling using standard methods. 9. Flow measurement for storm duration including bypassed & base flow 10. Mass Balance	1. Sediment chemical analysis for each sieve size and whole sample. 2. Additional chemical analysis for special parameters 3. Subdivide litter and debris into special categories 4. Baseflow measurement and chemical analysis 5. Other Analysis as Needed

There are many variables to consider in monitoring gross pollutants. Principal factors to investigate in developing a monitoring program for Gross Solids are the purpose of the monitoring program, fiscal constraints, desired accuracy, parameters to be monitored, whether the BMPs traps Gross Solids in a wet, dry, or combined condition, and time constraints for completion of the program. These factors should be used to determine a program level for monitoring. Three program levels have been defined. Level 1 is basic collection of samples with a minimal amount of laboratory analysis. Level 2 starts with Level 1 and adds intensive techniques to separate litter, debris, and sediment, and uses laboratory analysis to quantify basic individual parameters of concern. Level 3 programs are research programs customized for specific goals. Suggestions are made for Level 3 analysis, but these programs can be customized for any type of research needs. The program levels increase in cost and intensity of effort required as greater levels of accuracy are pursued. Note that the collection and analysis in each Level are minimum criteria, and additional techniques or parameters may be added as needed.

A complete copy of this committee report can be found at www.stormwaterauthority.com.

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