Appendix C Coastal Stormwater Management Practice Monitoring Protocol

This monitoring protocol provides information that can be used to evaluate the performance of green infrastructure and stormwater management practices in coastal Georgia. The protocol presents a simple, yet comprehensive monitoring approach that can be used to accurately evaluate the performance of a wide range of green infrastructure and stormwater management practices.

C.1 Introduction

On a national level, the need to monitor the performance of both green infrastructure and stormwater management practices is often overlooked. Given their widespread use and acceptance, the ability of green infrastructure and stormwater management practices to manage post-construction stormwater runoff rates, volumes and pollutant loads is rarely questioned. However, performance monitoring should be conducted to confirm that these practices are indeed protecting both on-site and downstream aquatic resources from the negative impacts of the land development process.

Currently, there are two primary sources of information on stormwater management practice performance. These include the *National Pollutant Removal Performance Database* (CWP, 2007), which summarizes 166 individual stormwater management practice performance studies, and the *International Stormwater Best Management Practice (BMP) Database* (WWE and Geosyntec, 2008), which contains information on the performance of over 300 individual stormwater management practices. Although these two databases contain a significant amount of data, several groups of green infrastructure and stormwater management practices are not well represented in either of them, including bioretention areas, infiltration practices and many other low impact development practices. Additionally, much of the information contained in the two databases was collected from sites located outside of the coastal plain (Novotney, 2007). Performance monitoring can be conducted in coastal Georgia to help fill both of these data gaps.

Keep in mind that no single monitoring effort can, by itself, be used to define performance of a stormwater management practice. However, it can contribute to the growing body of research on these practices, which will help define their effectiveness in protecting coastal Georgia's valuable aquatic resources from the impacts of the land development process. The results of individual monitoring efforts can also be used to improve the way that green infrastructure and stormwater management practices are designed and maintained.

C.1.1 What Stormwater Management Issues Can Monitoring Address?

Monitoring data collected from green infrastructure and stormwater management practices can be used to:

- Document the performance of commonly used practices
- Document the performance of new or innovative practices
- Document the effectiveness of these practices in removing local pollutants of concern (e.g., total suspended solids, nitrogen, bacteria) from post-construction stormwater runoff
- Evaluate whether or not certain design features (e.g., aquatic benches, vegetated forebays) improve performance
- Evaluate how local conditions (e.g., tidal influences, high groundwater) influence performance

- Determine whether or not the performance of the green infrastructure and stormwater management practices used in the coastal plain differs from the performance of practices used in other physiographic regions
- Provide a scientific basis for future modification or revision of this Coastal Stormwater Supplement (CSS)

C.2 Monitoring Program Development

Figure C.1 illustrates a process that can be used to develop a stormwater management practice monitoring program. Additional information about each step in this process is provided below.

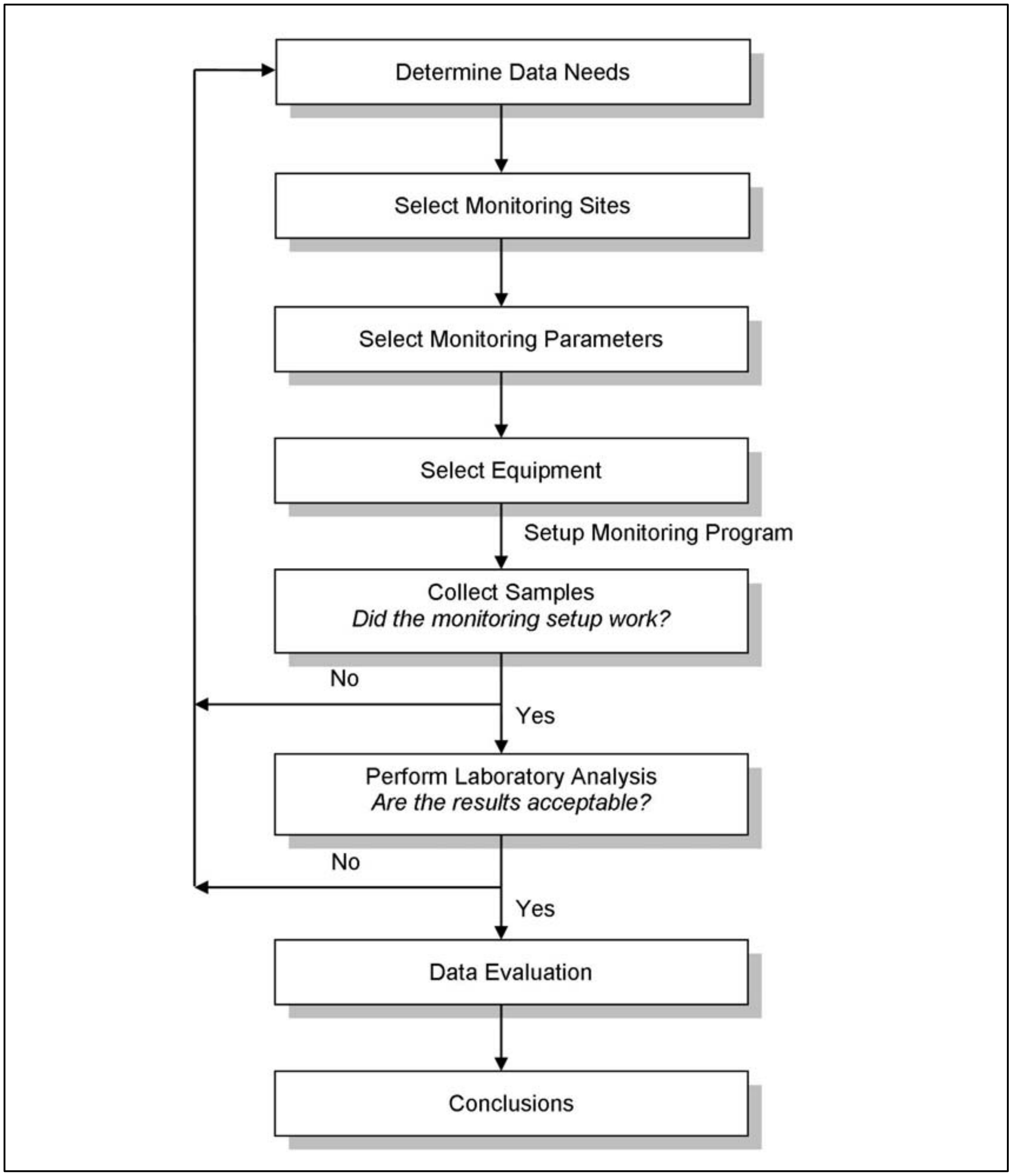


Figure C.1: Developing a Stormwater Management Practice Monitoring Program
(Source: Center for Watershed Protection)

C.2.1 Determining Data Needs

The monitoring program should be designed to collect the data necessary to produce a statistically valid measurement of performance. The amount and type of data that needs to be collected varies according to the method that will be used to evaluate the performance of the stormwater management practice. The two methods most commonly used are the mass efficiency method (also known as the *summation of loads* method) and the event mean concentration efficiency method (also known as *efficiency ratio* method). Table C.1 provides additional information about each of these methods.

Table C.1: Methods Used to Measure Stormwater Management Practice Performance		
Method	**Calculation**	**Data Needs**
Mass Efficiency	$[(SOL_{in} - SOL_{out}) \div (SOL_{in})] \times 100$	Precipitation, Inflow, Outflow, Pollutant Concentrations
Event Mean Concentration Efficiency	$[(Conc_{in} - Conc_{out}) \div (Conc_{in})] \times 100$	Precipitation, Pollutant Concentrations
Notes: SOL = sum of pollutant loads Conc = average pollutant event mean concentration		

Of the two methods, the mass efficiency method is recommended because it is generally considered to be more accurate than the event mean concentration method. The mass efficiency method also allows for a mass balance to be performed, which accounts for the stormwater runoff reduction and pollutant load removal provided by the green infrastructure or stormwater management practice.

Although the mass efficiency and event mean concentration efficiency methods are the two methods most commonly used to measure stormwater management practice performance, under certain conditions, they can result in over or underestimation of actual performance. For example, data collected from a stormwater management practice receiving inflow with a very high concentration of a given pollutant (e.g., total suspended solids) may show that the practice provides very good removal of that pollutant (on a percentage basis). However, the outflow from that same stormwater management practice may still contain an unacceptably high concentration of that particular pollutant (Strecker et al., 2004).

Conversely, data collected from a stormwater management practice that receives inflow with a very low concentration of a given pollutant (e.g., total nitrogen) may show that the practice is not performing very effectively (on a percentage basis). This is particularly true when the influent concentration of a particular pollutant approaches its irreducible concentration, which is the lowest possible concentration of a pollutant that can be observed in the field. Irreducible concentrations are dependent on the physical and chemical properties of each pollutant and often result from the pollutant production that occurs internally within a stormwater management practice (e.g., suspended solids and nutrients produced by decaying plant matter). When influent pollutant concentrations approach irreducible values, it becomes very difficult to further reduce the amount of those pollutants through stormwater treatment. In that case, it may be more useful to monitor the performance of a stormwater management practice relative to the achievable level of treatment (Schueler, 2000, ASCE and US EPA, 2002).

How Much Data Is Needed?

Measurements of stormwater management practice performance are only valid if a sufficient number of samples are collected and used in the measurement. The number of samples that need to be collected to produce statistically valid measurements of performance can be determined based on the pollutant of interest. In general, the more that the concentration of a particular pollutant varies from sample to sample and the smaller the difference between inflow and outflow concentrations, the greater the number of samples that must be collected to produce valid measurements of performance. As more samples are collected, the uncertainty associated with each of the individual samples is reduced and more statistically valid performance measurements of performance can be produced (Burton and Pitt, 2002).

Table C.2 shows the number of samples needed to characterize the performance of a stormwater management performance, with a 95 percent confidence level, based on the difference between mean inflow and outflow concentrations, typical sample concentrations (e.g., coefficient of variation of about 1) and a power of 80 percent. As can be seen from the table, if a high level of confidence is required (a 95 percent confidence level is typically used) and the difference between the mean inflow and outflow concentrations is small, a significant sampling effort will be needed. This could require a multi-year monitoring program.

Table C.2: Number of Samples Needed to Characterize the Performance of a Stormwater Management Practice Based on the Difference in Mean Inflow and Mean Outflow Concentrations (confidence level = 95%, power = 80%, coefficient of variation = 1)

Difference in Sample Set Means	80%	60%	40%	20%
# Samples Needed	20	50	75	300

Prior to initiating a monitoring program, some criteria should be established for determining when the monitoring results will be deemed statistically significant and when additional monitoring will be required. Once the number of samples required to produce a statistically valid measurement of performance has been determined, an iterative process may be needed to re-scope the monitoring effort to remain within budget and on schedule. When scoping a monitoring effort, it is reasonable to expect to collect between 5-10 paired storm event samples per year.

What Storm Events Should Be Sampled?

Consideration should not only be given to the number of samples that are needed to produce statistically valid measurements of performance, but also to the storm events that will need to be sampled. Ideally, samples would be collected during a variety of storm events with a range of intensities and durations in order to evaluate the performance of the stormwater management practice over a wide range of conditions (ASCE and US EPA, 2002). Although small rainfall events occur frequently in coastal Georgia (Appendix B) and can be used to quickly build the data set, they should not be overemphasized in the monitoring program (Burton and Pitt, 2002). A number of paired samples should be collected during larger, less-frequent rainfall events (e.g., 1-year, 24-hour storm, 10-year, 24-hour storm) to better characterize the performance of the stormwater management practice over a wider range of storm events. Historical rainfall data should be investigated to help determine a monitoring approach that might be used to evaluate practice performance over a wide range of storm events.

C.2.2 Selecting Monitoring Sites

The selection of good monitoring sites is an important step in developing a meaningful monitoring program. Selecting good monitoring sites will help ensure that the monitoring program stays on schedule and on budget and that enough samples will be collected to produce statistically significant measurements of performance.

When selecting monitoring sites, it is important to take into account the availability of existing monitoring data and the overall objectives of the monitoring program. A preliminary list of potential monitoring sites can be generated based on these considerations. Where there is an overall lack of local monitoring data, it may be better to select monitoring sites that will allow the performance of commonly used green infrastructure and stormwater management practices to be evaluated. Where new or innovative practices are being put in the ground, it may be better to select monitoring sites that will allow the performance of these practices to be evaluated. Regardless of the type of green infrastructure or stormwater management practice that will be monitored, it is always better to select monitoring sites that have characteristics that are representative of local conditions, rather than sites that have unique or unusual characteristics. This allows the results to be applied on a larger geographical basis, rather than just on the individual monitoring site.

Once a preliminary list of potential monitoring sites has been generated, each of the sites should be assessed using a set of basic screening factors. A set of potential screening factors is provided in Table C.3.

Table C.3: Potential Monitoring Site Screening Factors
• Type of Stormwater Management Practice
• Site Characteristics
• Stormwater Management Practice Design Features
• Complexity of Monitoring Situation
• Watershed Location
• Availability of Existing Monitoring Data
• Existing water quality criteria and designated use information
• Existing 303(d) impairments
• Existing Total Maximum Daily Load (TMDLs)
• Site Accessibility
• Site Safety
• Availability of Electricity
• Space to Install Equipment
• Property Ownership

At a minimum, the site screening process should consider the availability of existing monitoring data, the types of stormwater management practices installed at each potential monitoring site, the characteristics of each potential monitoring site and whether or not the stormwater management practices installed at each potential monitoring site were designed and constructed in accordance with the information presented in this CSS or an equivalent stormwater management manual. If a stormwater management practice was not well designed, it may be better to select another monitoring site; it is simply impractical to monitor a poorly-designed stormwater management practice, as the monitoring data will not provide any insights into the performance of that particular type of practice.

Another factor that should be considered during the site screening process is the complexity of the monitoring situation at each potential monitoring site. Although a monitoring program can be designed for both simple and complex monitoring situations (Table C.4), the design of a monitoring program for a simple monitoring situation tends to be less complicated than the design of a monitoring program for a complex one. Complex monitoring situations often require special sample collection procedures and devices (Table C.5), which increases the complexity of the monitoring program.

Table C.4: Simple and Complex Monitoring Situations

Monitoring Situation	Description
Simple Monitoring Situation (e.g., wet pond)	• Flow into and out of the stormwater management practice occurs at defined inlet and outlet structures and can be effectively characterized by sampling at the inlet and outlet.
Complex Monitoring Situation (e.g., bioretention areas, dry swales)	• Flow into or out of the stormwater management practice is distributed and cannot be effectively characterized by sampling at the inlet and outlet. • Flow must be redirected and concentrated at the inlet or outlet or additional sampling points must be established.

Another important factor to consider during the site screening process is the location of the potential monitoring site within the watershed. Selected monitoring sites can be spread across a large geographical area to permit comparisons from one monitoring site to the next or can be focused in a single priority area. The decision on whether to conduct a broad-based or focused monitoring program typically depends on the overall objectives of the monitoring program.

The site screening process may require both desktop and field investigations and can take some time to complete. Typically, only a small number of potential monitoring sites (e.g., 5 to 10%) will satisfy the screening criteria, so patience is certainly needed when conducting the site screening and selection process.

C.2.3 Selecting Monitoring Parameters

Typical monitoring parameters include:

- Nitrogen
- Phosphorus
- Total Suspended Solids (TSS)
- Biochemical Oxygen Demand (BOD)
- Fecal Coliform
- E. Coli
- Copper
- Lead
- Zinc
- Fats, Oils and Greases (FOG)
- Hydrocarbons

Some communities in the Coastal Nonpoint Source Management Area and Area of Special Interest may already be required to sample for one or more of these parameters. For example, due to National Pollutant Discharge Elimination System (NPDES) Stormwater Program requirements, Chatham County, which is a regulated Municipal Separate Storm Sewer System (MS4) community, is required to sample for BOD, TSS, nitrogen, phosphorus, copper, lead, zinc, FOG, fecal coliform and organic compounds. The selection of local monitoring parameters should take into account any pertinent permit requirements, existing monitoring data, existing resources, the overall objectives of the monitoring program and the local pollutants of concern. In coastal Georgia, the primary pollutants of concern are total suspended solids, nitrogen and bacteria (Novotney, 2007). If possible, these parameters should be monitored as a part of any monitoring program initiated in coastal Georgia.

C.2.4 Selecting Equipment

The equipment needed to collect samples and generate monitoring data on precipitation, inflow and outflow and pollutant concentrations (Table C.1) includes: rain gauges, flow meters, automated samplers and sample bottles. A digital camera is also recommended for photographic documentation of a monitoring site. If monitoring is to be conducted during cold weather months, snow gauges are also recommended to measure any precipitation that may occur in the form of snowfall. Rain and snow gauges should be installed as close as possible to the monitoring stations (e.g., inflow and outflow points) because precipitation can be highly variable even within a small geographic area. Manual rain gauges are also recommended to check the accuracy and consistency of different gauges installed on the monitoring site (ASCE and US EPA, 2002).

Automated samplers are recommended for sample collection. They eliminate the need for an operator to be on-site to perform sample collection and allow for the collection of flow-weighted, composite samples. Although an operator will not need to be on-site to collect samples, it is important to keep in mind that routine inspection and maintenance will need to be performed on all automated samplers to help ensure that the equipment will be functioning properly when a storm event does occur (ASCE and US EPA, 2002).

ISCO and American Sigma are two of a number of manufacturers that make automated sampling equipment that can be used to monitor the performance of stormwater management practices. These samplers are specifically designed for sampling stormwater runoff. They have flexible programming capabilities and can be programmed to begin collecting samples when a specific inflow or outflow rate is detected. These samplers can also be equipped with flow meters and rain gauges so that rainfall and flow data can be collected at the same time as water quality data. Many of the newest automated samplers can also be set up to interface with water quality monitoring probes, such as the YSI 6000, which can provide a continuous record of standard water quality parameters, such as temperature, salinity, pH and turbidity. The YSI 6000 can also be used to trigger sample collection when specific water quality conditions are detected in the inflow or outflow stream.

Although automated samplers are recommended for sample collection, it is important to note that they cannot be used to collect bacteria samples. Bacteria samples must be collected using sterile sample cells and must be preserved using ice. Manual collection of bacteria samples is required to ensure that these sample collection and holding procedures are not compromised during sample collection.

Note that even with specialized equipment, it can be difficult to collect water quality samples under complex monitoring situations. Flow into or out of these practices may occur as sheet flow, may be distributed among multiple inflow or outflow points or may occur underground (e.g., infiltration, groundwater interaction). Complex monitoring situations usually require paired site monitoring, where one monitoring site acts as a control and the other acts as a treatment. The variability in the characteristics of the two monitoring sites adds some uncertainty to the monitoring study, but paired site monitoring provides more accurate results for complex situations than a single site approach, where assumptions need to be made concerning any unmonitored and unaccounted for losses. Paired site monitoring can include one site with a stormwater management practice and one without, or it can include two sites with the same type of stormwater management practice as a way to monitor losses that may be difficult to measure or account for on a single site. Additional options for collecting samples under complex monitoring situations are presented in Table C.5.

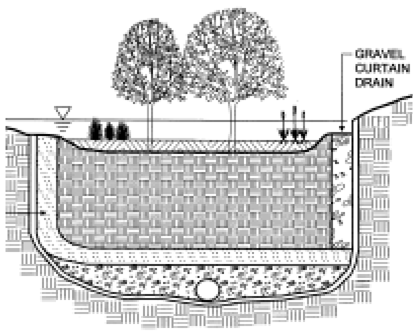
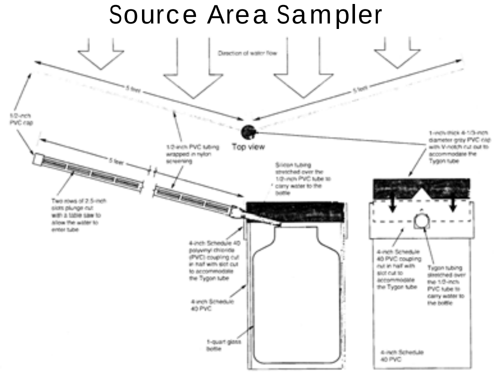
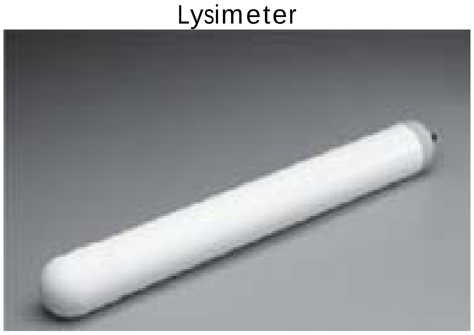
Table C.5: Options for Collecting Samples Under Complex Monitoring Situations	
Option	**Description**
Sump and Weir  Source: Smith et al. (No Date)	Install a defined sump and weir at the inflow or outflow point to collect and measure runoff that would have otherwise entered or exited the stormwater management practice as sheet flow
Underdrain  Source: Claytor and Schueler (1996)	Install an underdrain to collect and measure runoff that would have otherwise exited the stormwater management practice via infiltration
Source Area Sampler 	Use source area samplers to collect and measure runoff that would have otherwise entered or exited the stormwater management practice as sheet flow
Lysimeter  Source: Soilmoisture Equipment (1999)	Use lysimeters or soil water sampling devices to monitor the quality of water within the soil column immediately down gradient of the storm water management practice

Table C.5: Options for Collecting Samples Under Complex Monitoring Situations

Option	Description
Runoff Estimation $L = [(P)(R_v) \div (12)](C)(A)(2.72)$ Where: L = Pollutant load in influent (pounds) P = Rainfall depth (inches) R_v = Runoff coefficient, which expresses the fraction of rainfall that is converted into runoff C = Event mean concentration of the pollutant in urban runoff (mg/l) A = Area of the contributing drainage (acres) 12 and 2.72 are unit conversion factors Source: Schueler (1987)	Measure outflow and, using the Simple Method, information on pollutant event mean concentrations from the National Stormwater Quality Database and rainfall data, estimate the runoff and pollutant load that entered the stormwater management practice as sheet flow

C.3 Monitoring Procedures

Once monitoring data needs have been determined, monitoring sites and monitoring parameters have been selected and sampling equipment has been purchased, the next step is to set up the monitoring program and begin collecting data. This part of the process is described in more detail below.

C.3.1 Characterize Site Conditions

The characteristics a particular monitoring site will likely have some influence on the performance of the stormwater management practice that is being monitored. For example, the distribution of different land cover types within a stormwater management practice's contributing drainage will influence the type and amount of pollutants that are conveyed into the practice. For this reason, it is important to accurately characterize the site conditions before monitoring begins. The following information should be collected to accurately characterize the conditions of a monitoring site:

- Size of the contributing drainage area
- A narrative description of the contributing drainage area, including information about the different land uses found within
- An estimate of the amount of impervious cover found within the contributing drainage area
- A basic characterization of the pollutants conveyed to the green infrastructure or stormwater management practice
- An narrative history of the stormwater management practice, including information about its age, maintenance history and current condition
- As-built drawings to identify the design features (e.g., forebay, aquatic benches) that were included in the stormwater management practice

C.3.2 Select Monitoring Points

Monitoring stations should be established at the points where flow enters and exits the stormwater management practice. This facilitates a comparison of the quality of the stormwater runoff that is entering and exiting the practice. This comparison can be completed using either the mass efficiency method or the event mean concentration efficiency method (Table C.1). While selecting monitoring points is fairly straightforward in simple monitoring situations, selecting monitoring points in complex monitoring situations is more difficult. Complex monitoring situations typically require a specialized monitoring setup (Table C.4).

Accurate measurement of the flow into and out of the stormwater management practice is important. Inaccurate measurement of inflow or outflow is the single largest source of error in efforts to monitor the performance of individual stormwater management practices. It is important to note that, as the complexity of the monitoring situation increases, so does the difficulty in obtaining accurate measurements of both inflow and outflow.

C.3.3 Collect Samples

Data should be collected to satisfy the needs of the selected performance measurement method (Table C.1). Automated sampling is recommended because it eliminates the need for an operator to be on-site for sample collection and allows for the collection of flow-weighted, composite samples. Samples should be collected throughout the duration of each individual storm event, rather than for specified periods at the very beginning of each event. This is due to the fact that the “first flush” effect is not always observed for all monitoring parameters (Maestre et al., 2004) and can vary depending upon site and rainfall characteristics (Strecker et al., 2005). Therefore, it is recommended that samples be collected throughout the duration of each rainfall event and composited on a flow-weighted basis prior to laboratory analysis. These composite samples provide more accurate results than composite samples collected during only the first 30 minutes or 1 hour of a storm event (Maestre et al., 2004).

After the initial sampling and laboratory analyses have been completed, preliminary data evaluation should be completed to determine if the monitoring program is working and providing the necessary data. If not, adjustments can be made to ensure that the program will provide the data necessary to produce statistically valid measurements of stormwater management practice performance.

What Special Sample Collection Procedures Should Be Observed?

Carefully planned and executed sample collection is required to achieve meaningful results. Sample collection and handling does little to alter the in-situ concentrations of many common monitoring parameters but, for others, it can cause significant changes in concentration. For this reason, sample collection and handling protocol should be followed to ensure that laboratory results are representative of the actual conditions found at the monitoring site. Additional information about proper sample collection and handling techniques is provided in *Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments* (CWP and Pitt, 2004). The *Stormwater Effects Handbook: A Toolbox for Watershed Managers, Scientists and Engineers* (Burton and Pitt, 2002) is another good resource for information about proper sample collection and handling techniques.

What Sample Collection Problems Can Be Expected?

Sample collection always appears to be easier on paper than it is in real life. Odds are that a number of problems will be encountered as samples are being collected during a monitoring study. Problems commonly encountered when monitoring green infrastructure and stormwater management practices include:

- Sensitive or sticky triggers on automated sampling equipment that cause problems with sample collection
- Extreme weather events, such as extended droughts and tropical storms, that cause damage to sampling equipment and extend the required length of the monitoring study
- Limited capacity of automated sampling equipment that results in samples being collected for only part of a storm event
- Trash and debris loads that cause damage to sampling equipment
- Vandalism that causes damage to sampling equipment
- Samples that do not account for the total pollutant load contained in either the inflow or outflow, which causes problems when evaluating the sample data

Precautions, such as installing trash racks and other protective measures to prevent equipment damage, can often be taken to address many of these and other common sample collection problems.

C.3.4 Perform Laboratory Analysis

Once they are collected, samples can be analyzed for selected monitoring parameters in-house or at a contract laboratory. The decision on whether to conduct analysis in-house or at a contract laboratory depends upon a number of factors, including the availability of lab space and equipment, staff expertise, staff time, cost, safety considerations and how quickly the sampling results are needed.

C.3.5 Data Evaluation and Management

Once laboratory results are available, they can be used to evaluate the performance of the stormwater management practice using either the mass efficiency method or the event mean concentration efficiency method (Table C.1). Results should not be considered conclusive until a sufficient number of samples have been collected. After conclusive results have been obtained, they should be compared to national (e.g., CWP, 2007) or regional (e.g., data taken only from sites in coastal Georgia) performance data to obtain a sense of how the performance of the practice compares with other similar stormwater management practices.

Paired box and whisker plots of influent and effluent quality are also useful data evaluation tools. Box and whisker plots typically illustrate the median, the 25th and 75th percentiles and the upper and lower 95 percent confidence intervals (Strecker et al., 2004). Figure C.2 presents an example box and whisker plot for the concentration of copper present in the flow into and out of a bioretention area.

Stormwater management practice monitoring can generate a considerable amount of information in a variety of formats. Consequently, both hard copy and electronic information needs to be stored in a manner that will make it easy to be both retrieved and transferred. A central file can be used to house hard copy information, while a single electronic database can be used to house information collected in digital format (ASCE and US EPA, 2002).

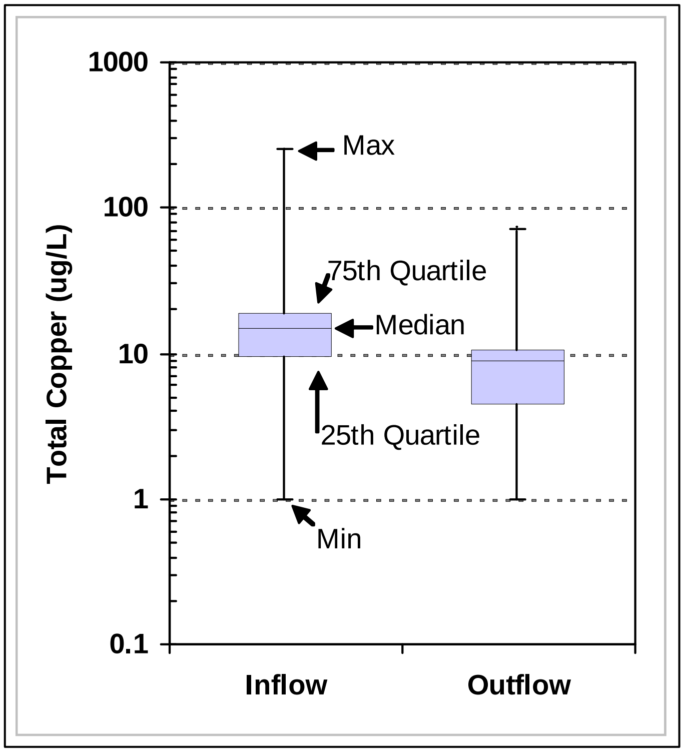


Figure C.2: Example Box and Whisker Plot for a Bioretention Area
(Source: Center for Watershed Protection)

What Data Evaluation and Management Issues Can Be Expected?

Quality control is necessary to ensure that useful and accurate data is collected throughout the duration of the monitoring program. Data should be reviewed as it becomes available to identify any results that may indicate that samples are being incorrectly collected, handled or analyzed. Any questionable results should not be used in the calculations performed to define stormwater management practice performance. Recommended quality controls include checking that the timing on all automated sampling equipment is synchronized, that runoff is entering and exiting the stormwater management practice as expected and that an equivalent number of aliquots are being collected at both the inflow and outflow points during storm events.

Particular attention should be given to “non-detected” values returned from laboratory analyses. These results can present problems during data evaluation.

The detection limit is the lowest concentration of a monitoring parameter that can be measured in the laboratory with a certain degree of confidence. If a parameter is “non-detected” in the laboratory analysis, it means that the concentration of that parameter is less than the detection limit for that parameter. If either a few or many of the observations are below the detection limit, they will not present a serious problem during data analysis. However, if between 25% and 75% of the observations are below the detection limit, statistical data analysis will be severely limited. In this case, it would be better to have the concentrations for all parameters, even if they are below a parameter’s detection limit (Burton and Pitt, 2002).

The amount of stormwater runoff reduction provided by a stormwater management practice should also be estimated when evaluating practice performance. This is perhaps the most crucial piece of information needed in complex monitoring situations and can be used to confirm that green infrastructure practices are providing the runoff reduction that this CSS "credits" them with providing. Under complex monitoring situations, stormwater runoff volumes usually must be estimated at either the inlet or outlet because flow into or out of these practices may occur as sheet flow, may be distributed among multiple inflow or outflow points or may occur underground (e.g., infiltration, groundwater interaction) and cannot be directly measured.

C.4 Budgeting

An example budget for monitoring an individual stormwater management practice, under both simple and complex monitoring situations, is provided in Table C.6. Keep in mind that the table provides general budgeting guidance and that the total budget for a local monitoring program will vary according to a number of factors, including the length of the monitoring study, the equipment used, local site constraints and the laboratory analysis procedures used.

Table C.6: Example Budget for Monitoring an Individual Stormwater Management Practice

	Simple Monitoring Situation			Complex Monitoring Situation		
	Staff Time	Unit Cost	Total Cost	Staff Time	Unit Cost	Total Cost
Planning	**5%**			**6%**		
Background Research[1]	40 hr	$50/hr	$2,000	40 hr	$50/hr	$2,000
Desktop Analysis[2]	32 hr	$50/hr	$1,600	32 hr	$50/hr	$1,600
Field Reconnaissance and Site Selection	32 hr	$50/hr	$1,600	32 hr	$50/hr	$1,600
Site Characterization	8 hr	$50/hr	$400	16 hr	$50/hr	$800
Monitoring Plan Development	16 hr	$50/hr	$800	32 hr	$50/hr	$1,600
Subtotal			**$6,400**			**$7,600**
Implementation	**95%**			**95%**		
Equipment[3]			$15,000			$17,000
Equipment Installation and Maintenance[4, 5]	256 hr	$50/hr	$12,800	512 hr	$50/hr	$25,600
Training	32 hr	$50/hr	$1,600	32 hr	$50/hr	$1,600
Sample Collection[6]	512 hr	$50/hr	$25,600	512 hr	$50/hr	$25,600
Sample Storage and Transport			$10,000			$10,000
Laboratory Analysis[7]		$200/ea	$8,800	$200/ea		$8,800
Data QA/QC	40 hr	$50/hr	$2,000	40 hr	$50/hr	$2,000
Data Evaluation and Management	80 hr	$50/hr	$4,000	80 hr	$50/hr	$4,000
Final Report	80 hr	$50/hr	$4,000	80 hr	$50/hr	$4,000
Subtotal			**$83,800**			**$98,600**
Planning and Implementation						
Total			**$90,200**			**$106,200**

Notes:
1) Includes determination of data needs, selection of monitoring parameters and preliminary identification of potential monitoring sites
2) Includes preliminary review of potential monitoring sites and generation of maps for field reconnaissance (major tasks include: preliminary site selection, preliminary site characterization, generate field maps)

Table C.6: Example Budget for Monitoring an Individual Stormwater Management Practice
Notes: 3) Equipment for simple monitoring situation includes 2 automatic samplers, triggering sensors, pump, lumber, concrete, battery, waders, clipboards, fieldbooks, first aid kits; equipment for complex monitoring situation includes 2 automatic samplers, triggering sensors, pump, lumber, concrete, battery, underdrain, sump and weir at inlet, waders, clipboards, fieldbooks, first aid kits 4) Installation for simple monitoring situation includes 3 people for 2 days; installation for complex monitoring situation assumes 3 people for 4 days. 5) Assumes maintenance burden of 1 person at 2 hours per week for 2 years. 6) Includes 2 people for 8 hours for each storm event; assumes 30 storm events and 2 baseflow events will be sampled; out of the 30 sampled events, only 20 are expected to meet QA/QC standards. 7) Assumes contract laboratory analysis for nitrogen, phosphorus, total suspended solids, fecal coliform, zinc, lead and hydrocarbons; assumes one composited inflow and one composited outflow sample will be analyzed for 20 storm and 2 baseflow events.

C.5 Alternative Monitoring Methods

As Table C.6 shows, it can be expensive to accurately evaluate the performance of individual green infrastructure and stormwater management practices. Given limited resources, many communities in coastal Georgia will not be able to conduct intensive monitoring on more than a handful of green infrastructure and stormwater management practices. To overcome this constraint, and still collect valuable information about stormwater management practice performance, communities can complete less intense field surveys that evaluate physical indicators of practice performance, such as design features, sediment accumulation and vegetation health.

Although less than a dozen of this type of visual survey have been conducted around the country, they have been extremely valuable in identifying problems with existing stormwater management practice design, as well as in defining new directions for stormwater management practice installation and maintenance. These synoptic surveys are relatively low cost, but can yield important information that can be directly incorporated into local stormwater design guidance, development review procedures and day-to-day operations. Examples of these types of surveys include:

- A study conducted by the U.S. EPA on erosion and sediment control (E&SC) practices at construction sites, in a community thought to have one of the strongest E&SC programs in the nation, found that poor installation and implementation of E&SC practices was a widespread problem (Malcolm et al., 1990)
- Investigations into the pollutant dynamics and habitat quality of stormwater ponds (Campbell, 1995, Leersnyder, 1993, Dewberry and Davis, 1990, Oberts and Osgood, 1988, Bascietto and Adams, 1983).
- Assessments of the failure rate and functional life span of infiltration practices (Galli, 1993, Hilding, 1993).
- Investigations into the performance of biofilters and oil/grit separators (Reeves, 1995, Shepp, 1995).

While these surveys typically only involve visual inspections, they can be supplemented with some water quality sample collection and analysis in an effort to determine whether or not a particular stormwater management practice is working to protect local aquatic resources from the negative impacts of the land development process. Interviews with adjacent residents or property owners can also be used to supplement the results of these visual surveys.

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