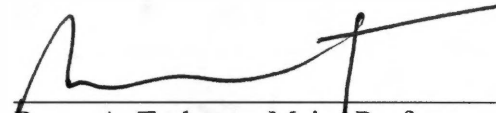
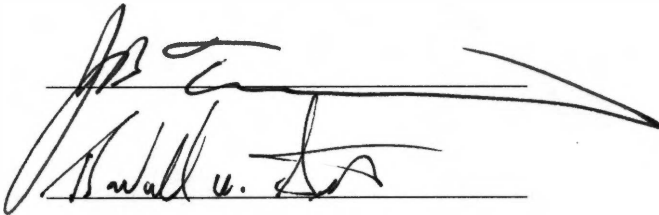


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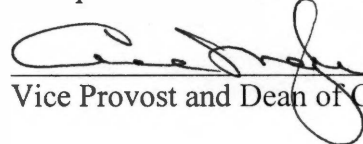
I am submitting herewith a thesis written by Robert G. Morton entitled "Maintenance Elements and Guidelines for Post-Construction Best Management Practices." I have examined the final paper copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Environmental Engineering.


Bruce A. Tschantz, Major Professor

We have read this thesis
and recommend its acceptance:



Accepted for the Council:


Vice Provost and Dean of Graduate Studies

Maintenance Elements and Guidelines for Post-Construction Best Management Practices

A Thesis Presented
for the
Master of Science Degree
The University of Tennessee, Knoxville

Robert G. Morton

December 2002

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List of Abbreviations

APWA	American Public Works Association
ARC	Atlanta Regional Commission
ASCE	American Society of Civil Engineers
BMP	Best Management Practice
COD	Chemical Oxygen Demand
COK	City of Knoxville, Tennessee
CSO	Combined Sewer Overflow
CSQTF	California Stormwater Quality Task Force
CWA	Clean Water Act of 1972
EPA	United States Environmental Protection Agency
FEMA	Federal Emergency Management Agency
F-n	Filtration BMP
GIS	Geographical Information System
I-n	Infiltration BMP
KCDEPW	Knox County Department of Engineering and Public Works
MCDEP	Montgomery County Department of Environmental Protection
MCSFOWG	Montgomery County Stormwater Financing Options Working Group
MDE	Maryland Department of the Environment
MEP	Maximum Extent Practicable
MNDC	Metropolitan Government of Nashville and Davidson County
MS4s	Municipal Separate Storm Sewer Systems
MSD	Metropolitan Sewer District
MTAS	Municipal Technical Advisory Service
N	Nitrogen
NFIP	National Flood Insurance Program
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRDC	Natural Resources Defense Council
NS	Non-Structural BMP
NVPDC	Northern Virginia Planning District Commission
O&M	Operation and Maintenance
O-n	Open Channel BMP
P	Phosphorous
PA	Permitting Authority
PACD	Pennsylvania Association of Conservation Districts, Inc.
PBM	Practical Best Management of Georgia

List of Abbreviations Continued

P-n	Ponding BMP
SMRC	Stormwater Manager's Resource Center
SWPPP	Stormwater Pollution Prevention Plan
TDEC	Tennessee Department of Environment and Conservation
TGR	Tennessee Growth Readiness
TSS	Total Suspended Solids
TWRRC	Tennessee Water Resources Research Center
VDCR	Virginia Department of Conservation and Recreation
W-n	Constructed Wetlands BMP

Chapter I - Introduction

Purpose and Scope

The purpose of this thesis is fourfold:

- To review the importance of good stormwater system maintenance for stormwater quality and quantity management;
- To identify and summarize the elements of good maintenance protocol and practices;
- To recommend stormwater management facility maintenance guidelines to local officials and public.
- To develop a guide to serve Tennessee municipalities in developing a maintenance program for stormwater management systems.

The general public rarely grasps the importance of a stormwater management and conveyance system until the facility fails to work or causes damage and problems. Structures such as detention ponds, catch basins, and infiltration basins often receive attention only when the local agency receives complaints. Even then, (as in the case of flooded streets or turbid water) the problem is often forgotten when the water subsides. It is only when there is loss of life and/or property damage that citizens want to know the reason for the failure of the system.

In many cases, failure can be averted by a comprehensive stormwater facility maintenance plan. It has been written, "This purpose [of a stormwater system] is not accomplished if the system is dysfunctional – for example if the system is blocked or has collapsed and the flow of runoff is obstructed. System failure and the resulting flooding, property damage, and threat to public health and safety can be avoided by routine preventative maintenance" (Chandler, 2001). A good preventative maintenance plan

includes a regular inspection routine and regular preventative maintenance tasks. The purveyors of such a plan are typically the owners of the property on which the stormwater structure is located, whether the owners are private citizens or an industrial or governmental entity. However, there are several obstacles that need to be overcome prior to implementing a maintenance plan. These are described below.

The owners of the property need to be educated and aware of their maintenance responsibility

In many cases, the owners do not realize that it is their responsibility to maintain stormwater best management practices (BMPs) located on their property. There are numerous reasons for this. The owner may not understand his responsibility for maintenance or realize that the BMP is on his property. In cases such as commonly owned grounds in subdivisions, this responsibility is further clouded by ambiguity in property ownership. A BMP on common grounds may be perceived to be situated on one parcel in particular, and the BMP is never maintained. Such misunderstandings require awareness education for the property owners.

Many homeowners equate stormwater management with municipal operations. Since municipalities maintain many roadway appurtenances, such as catch basins and inlets, landowners often believe that all stormwater management structures are the municipality's responsibility. Education of private landowners is vital to the long-term function of stormwater structures and BMPs.

The owners need to be aware of the location, function and purpose of such facilities

Prior to purchasing land, the prospective owner should be aware of the stormwater BMPs in a subdivision or on the property itself. Furthermore, it is vital that all owners understand the function of BMPs and the purpose of the stormwater management system. Understanding the system's function and its relation to the receiving stream and

watershed as a whole may awaken the owner to the importance of the stormwater drainage system, and encourages the owner to take responsibility.

The owners need to know what to inspect and the maintenance task to perform

When the owners know the function of the stormwater BMPs, the importance of maintaining them becomes more prevalent. It is very important for the owner to know key inspection and maintenance items for each BMP. A landowner may actively perform maintenance procedures, but unless properly trained and educated, will fail to perform the vital tasks that ensure the performance of the BMP. For example, the owner of an infiltration basin may mow the grass in the basin each month, but does not realize that he should remove the grass clippings to ensure peak performance. Each maintenance task should be understood prior to ownership.

The owners need to know when to inspect the BMP and perform maintenance tasks

The owner must understand the extent and frequency of inspection. Regularity of inspection is just as important as knowing what task to perform. An inspection and maintenance program provides no benefit if it is not actively pursued. As with anything, if a facility is not inspected and maintained regularly, it is less likely to perform effectively as intended and may even fail. Maintenance schedules are common in many fields, such as the automotive industry. An automobile would not be expected to last very long if important inspection and maintenance tasks such as checking fluid levels and tire tread were not heeded. The same is true for stormwater BMPs. If a regular inspection and maintenance program is not defined or followed, then the BMP cannot be expected to perform well or last long.

The owners need to know the consequences of not developing such a plan

Without proper information and education, it is impossible for owners to know the consequences of not performing regular inspection and maintenance. Rainfall is a

random occurrence and cannot be accurately predicted far in advance. While one storm may be passed through a system with no little or no noticeable effect, another storm may push the same system to failure. A properly designed and maintained system will not fail under normal circumstances; a properly designed and an ill-maintained system will eventually fail. Failure of stormwater BMPs often leads to legal, and other economic consequences.

The material developed in this thesis discusses each of the preceding topics and is intended to serve as a guide for Tennessee municipalities, counties, and local regulators. The discussion of maintenance will be limited to the post-construction best management practices listed in the Tennessee Guide to the Selection and Design of Stormwater Best Management Practices prepared by the Tennessee Water Resources Research Center. (TWRRC, 2002) These practices are summarized in Table 1.1.

The BMPs are separated into two categories: structural and non-structural. A structural BMP is “a tangible modification associated with a physical system component” (Pyzoha, 1994). A non-structural BMP works to alleviate the cause of the problem (Pyzoha, 1994). In other words, while structural BMPs physically control stormwater runoff, non-structural BMPs work to lessen the effect of stormwater runoff.

David Pyzoha writes that non-structural BMPs (denoted by “NS”) are BMPs that “identify with alleviating the cause of problems” (Pyzoha, 1994). BMPs in the matrix above do not physically add more capacity to the stormwater conveyance system, but increase the effectiveness of the existing facilities.

The structural BMPs have been separated into five categories: ponding BMPs (denoted by “P”), wetland BMPs (denoted by “W”), infiltration BMPs (denoted by “I”), filtration BMPs (denoted by “F”), and open channel BMPs (denoted by “O”). Ponding BMPs manage stormwater by detaining stormwater and controlling the release to a rate of no more than the pre-development conditions. Wetland BMPs incorporate many of the same

features as ponding BMPs, but are designed to encourage aquatic plants and animals. Infiltration BMPs are designed to control stormwater runoff by encouraging water to infiltrate into the soil instead of flowing above ground. Filtration BMPs are designed to enhance stormwater quality by treating stormwater by filtering it through a vegetative or porous media. Finally, open channel BMPs are designed to convey stormwater runoff, while encouraging stormwater infiltration into the soil.

Background

Prior to the Environmental Protection Agency's (EPA) Federal Water Pollution Control Act (also known as the Clean Water Act) of 1972, only a third of the nation's waters were safe for fishing and swimming, and agricultural runoff resulted in the erosion of 2.25 billion tons of soil into our nation's waters (<http://www.epa.gov/owow/cwa/history.htm>,

Table 1.1- Best Management Practice Matrix

<i>BMP</i>	<i>Symbol</i>	<i>Category</i>	
NON-STRUCTURAL		Water Quantity	Water Quality
Comprehensive Planning, Zoning, Ordinances, and Codes	NS-01	X	X
Landscaping and Vegetative Control Practices	NS-02	X	X
Public Outreach and Education Awareness	NS-03	X	X
Good Housekeeping	NS-04		X
Urban Stormwater Pollution Prevention Plans	NS-05		X
Non Stormwater Discharges to Storm Drains	NS-06		X
STRUCTURAL			
Detention (Dry) Basin	P-01	X	X
Retention (Wet) Basin	P-02	X	X
Alternative Storage Measures	P-03	X	X
Constructed Wetlands	W-01	X	X
Infiltration/Percolation Trench	I-01	X	
Infiltration Basin	I-02	X	X
Underground Drainage Systems	I-03		X
Porous Pavement	I-04	X	
Catch Basin Inserts/Media Filter	F-01		X
Oil/Water Separator	F-02		X
Filter and Buffer Strips	F-03	X	X
Filter/Adsorption Bed	F-04		X
Bioretention Basins (Rain Gardens)	F-05	X	X
Swale (Open Channel Systems)	O-01	X	X

Source: Tschantz, Gangaware, Morton. Tennessee Guide to the Selection and Design of Stormwater Best Management Practices (BMPs), 2002.

2002). The primary objective of the Clean Water Act is to restore and maintain the integrity of the nation's waters through two fundamental goals: by eliminating the discharge of pollutants into waterways, and by achieving water quality levels that are suitable for fishing and swimming (<http://www.epa.gov/owow/cwa/history.htm>, 2002). The Clean Water Act establishes a framework of standards, tools, and financial assistance to remedy the problem of water pollution (<http://www.epa.gov/owow/cwa/history.htm>, 2002).

The EPA's vehicle for eliminating point source pollution is through the National Pollutant Discharge Elimination System (NPDES), created under Section 402 of the Clean Water Act (CWA). Although this system was first developed to regulate discharges emanating from treatment plants, the regulations were later applied to stormwater runoff sources as well. In hopes of regulating the vast number of stormwater runoff point sources, in 1987, Congress modified the CWA to address stormwater discharges in two phases (Chandler, 2001).

The Phase I permitting program was issued on November 16, 1990 and required NPDES permits for all medium and large municipal separate storm sewer systems (MS4s) serving populations over 100,000, and for other industrial and municipalities designated by the permitting authority. In addition, this permit is required for all construction sites of five or more acres (EPA, 2002).

The Phase II permitting program was issued on December 8, 1999, and covers any MS4 that is not already designated and regulated as a medium or large MS4 under Phase I and construction sites between 1 and 5 acres (EPA, 2002). State agencies will issue the Phase II permit in December 2002, and the areas under Phase II regulations will file for the permit by March 10, 2003. According to the EPA, the affected MS4s will be required to "develop, implement, and enforce a storm water management program to: Reduce the discharge of pollutants to the maximum extent practicable (MEP); Protect water quality; Satisfy the appropriate water quality requirements of the Clean Water Act" (EPA, 2002).

In addition to evaluation/assessment efforts and record keeping, the stormwater management program must include “Six Minimum Control Measures” developed by the EPA as steps in eliminating point source pollution.

- Public Education and Outreach
- Public Involvement/Participation
- Illicit Discharge Detection and Elimination
- Construction Site Stormwater Runoff Control
- Post-construction Stormwater Management in New Development and Redevelopment
- Pollution Prevention/Good housekeeping for Municipal Operations

Each MS4 must submit a Notice of Intent (NOI) to the permitting authority, and identify BMPs, measurable goals, timing and frequency of actions, and responsible persons for performing each minimum control measure.

Public Education and Outreach

To satisfy this requirement, communities must distribute educational materials (such as flyers or commercials) or conduct outreach activities. The municipality may find that a partnership with local civic organizations will aid in distribution of materials. Topics of education include the impacts of stormwater discharges on water bodies and steps the public can take to reduce stormwater pollutants and ensure the functionality of the stormwater system.

Public Involvement/Participation

This step allows the public to participate in stormwater activities. According to a presentation given by the Municipal Technical Advisory Service of the University of

Tennessee (MTAS), a vital step is identifying those who have the most at stake in water quality issues and getting them involved (MTAS, 2002). This includes political and industrial leaders, as well as farmers, kids, and land use groups. Some examples of public involvement are stormwater management panels, and Adopt-a-Stream programs.

Illicit Discharge Detection and Elimination

This program is intended to find and remove illegal discharges such as sanitary wastewater, effluent from septic tanks, and improper disposal of automotive and household toxic effluents (i.e. used antifreeze poured down the storm drain). To accomplish this task, communities must do the following: develop a sewer system map of all outfalls and receiving waters, develop an ordinance or similar means to prohibit non-stormwater discharges, implement a detection plan to address illicit discharges (such as dye and smoke tracing and video), and inform the public of hazards associated with illegal discharges.

Construction Site Stormwater Runoff Control

Communities must develop a program to reduce pollutants from construction activities that disturb at least one acre. Measures of controlling construction site stormwater can be found in Tennessee Department of Environment and Conservation's (TDEC) Tennessee Erosion and Sediment Control Handbook (TDEC, 2002). Also, the community must use an ordinance or other regulatory means, to penalize those that don't utilize proper erosion and sedimentation control practices, or control waste on the site. This measure is already in place as a program administered by TDEC.

Post-construction Stormwater Management in New Development and Redevelopment

To satisfy the fifth measure regarding post-construction stormwater management in developments, the EPA requires the following steps from designated municipalities:

- Develop a program, using an ordinance or other regulatory means, to address runoff from new development and redevelopment projects that disturb at least an acre;
- Implement strategies with a combination of structural and/or non-structural BMP's
- Ensure adequate long-term operation and maintenance (O&M) of BMPs.

Developing an ordinance to address stormwater runoff establishes legal framework to help enforce good stormwater management. In order to physically control the quantity and quality of the stormwater, municipalities should select BMPs that are best suited for their need. Establishing a long-term operation and maintenance program is a very important step for municipalities in complying with Phase II requirements, but is also crucial in protecting the water quality of the area. Additional information on post-construction stormwater management can be found in the Tennessee Guide to the Selection and Design of Stormwater Best Management Practices prepared by the Tennessee Water Resources Research Center (TWRRC, 2002).

Pollution Prevention/Good housekeeping for Municipal Operations

Communities must develop an O&M program to prevent or reduce pollutant runoff from municipal operations. This program will include scheduled inspection and maintenance, as well as employee training, which will prevent and reduce stormwater pollution from maintenance activities (EPA, 2002).

Implementation of these measures is mandatory and will be enforced by TDEC, the permitting authority (PA). Together, the Six Minimum Control Measures work to reduce pollutants in stormwater to the maximum extent practicable. Furthermore, municipalities will select measurable goals to quantify the progress of the stormwater program

implementation and the performance of selected BMPs. TDEC will then be able to track the municipality's progress towards achieving cleaner water.

Literature Review

This thesis was derived from a thorough literature search, with information supplied from textbooks, periodicals, pamphlets, stormwater management manuals, videos, and internet web sites.

The topic of stormwater BMPs has been addressed more since the advent of the Phases I and II NPDES programs. Many publications have been issued by the United States EPA regarding structural and non-structural BMPs. Many of them, such as the "Storm Water Phase II Fact Sheets", list the implementation of structural and non-structural BMPs as guidelines for implementing minimum control measures (EPA, 2000). In addition, the EPA has released a listing of Best Management Practices for NPDES Storm Water Phase II (EPA, 2002). One item included in this list is that of BMP Inspection and Maintenance. The EPA notes, "to maintain the effectiveness of postconstruction storm water control best management practices (BMPs), regular inspection of control measures is essential" (EPA, 2002).

Local entities have been active in developing ideas to aid in Phase I and II compliance. Montgomery County, Maryland has been a leader in stormwater quality issues since the 1960's. The county has been active in publishing information regarding stormwater BMP maintenance. One such publication is "Maintaining Urban Stormwater Facilities – A Guidebook for Common Ownership Communities" (MCDEP). The county also addressed issues such as citizen ownership and BMP maintenance needs in "Stormwater Alert" and financing the maintenance program in "Policy and Program Options for Montgomery County Stormwater Management" (MCSFOWG, 1999).

Another local entity that has published useful information regarding stormwater management is the Northern Virginia Planning District Commission, which has published structural (NVPDC, 1992) and non-structural (NVPDC, 1996) BMP handbooks, as well as a maintenance guide (NVPDC, 2000).

Many state environmental departments have followed suit in publishing stormwater BMP manuals and other information regarding Phase II compliance, since 43 states act as the Permitting Authorities for the program. (EPA, 2002) Some manuals that have been cited frequently include California (CSQTF, 1993), Georgia (ARC, 2000), Maryland (MDE, 2000) and Virginia (VDCR, 2001). In many cases, the state stormwater BMP manuals are based on other existing manuals. For example, the Tennessee manual (TWRRC, 2002) drew heavily upon the City of Knoxville's manual (COK, 2001), which was adapted from California's manual.

In some cases, interest groups have taken a large role in providing useful information regarding stormwater BMPs. One such group is the Center for Watershed Protection (www.stormwatercenter.net), whose website provides manuals for construction site, post-construction, and industrial BMPs, ordinances, and maintenance checklists. In addition, the American Society of Civil Engineers (ASCE) has worked to compile a database displaying BMP performance (www.bmpdatabase.org). It was designed to help officials decide upon which BMPs may be appropriate for their area. Another group that has been instrumental in expanding the public knowledge of stormwater management is the American Public Works Association. Their guides, *Designing and Implementing an Effective Storm Water Management Program* (APWA, 2000) and *Urban Stormwater Management* (APWA, 1981) each stress the importance of maintaining stormwater BMPs and give guidelines towards implementing a maintenance program.

In most cases, the topic of maintenance of these structures is mentioned, but rarely adequately addressed. As mentioned previously, the EPA and other state and local governmental agencies have developed valuable maintenance resources. Many

publications have been composed to supplement BMP information. Two such publications are Implementing a Stormwater Management Program (Pyzoha, 1993), and Municipal Storm Water Management (Debo and Reece, 1995). These publications provide valuable information on maintenance programs, from creation to implementation of the program. Ben Urbonas wrote another guide and Peter Stahre entitled Stormwater Best Management Practices and Detention for Water Quality, Drainage, and CSO Management (Stahre and Urbonas, 1993). This reference, although written especially for detention facilities, includes helpful information regarding inspection and maintenance, including key maintenance issues for each detention BMP.

Other graduate students at the University of Tennessee, Knoxville, have previously explored the topic of stormwater BMPs. Terry E. Romans completed research on the performance of Knoxville, Tennessee detention ponds, and found that many of these ponds deficient performance were attributed to poor maintenance practices (Romans, 1997). Chad R. Wagner did research on the effectiveness of other stormwater BMPs, namely catch basin inserts, which require consistent maintenance (Wagner, 1999). Kelie A. Hayden's thesis was presented as a guide to BMP selection, and discussed maintenance costs attributed to each BMP (Hayden, 2000). Furthermore, Jacob S. Chandler (2001) developed his thesis on issues more directly related to maintenance of specific stormwater BMPs, and included stormwater maintenance protocols, which were drawn upon heavily in this work (Chandler, 2001).

Chapter II – What Is a Maintenance Program and Why Have One?

The purpose of a local or municipal stormwater management system is to manage surface water runoff in a manner that does not increase the quantity of runoff discharged prior to development or redevelopment, or decrease the quality of water discharged.

Irresponsible management and poor stewardship often lead to a breakdown of one or more of the system's components, and a compromise of water quality and quantity management.

Review of Drainage Law

According to Tschantz, there are three basic common law rules concerning stormwater drainage: the civil law rule, which prohibits interference with surface water's natural flow; the common enemy rule, under which each property owner fights the water problem any way he can; and the doctrine of riparian rights, which is the basis for the existing Tennessee laws concerning water use and drainage (Tschantz, 2002). The doctrine of riparian rights can be stated as follows:

...each riparian owner has an equal right to have the stream flow through his land in its natural channel, without material diminution in quantity or alteration in quality but with this limitation or qualification, however, that each proprietor is entitled to the reasonable use of the water for domestic, agricultural or manufacturing purposes (American Association, Inc. v. Eastern Kentucky Land Co., 2 Tenn. Ch. App. 132, 173 (1901), affirmed by Tenn. Sup. Ct. without modification). (Tschantz, 2002)

Generally, the law accords the upstream property owner an easement for drainage of surface water across lower land to which it naturally flows. Controversies and lawsuits follow when the quality and quantity of flow is altered prior to discharging onto neighboring lands.

What Is a Maintenance Program?

An important distinction must be made between inspection and maintenance. The purpose of inspection is to identify current and potential problems. A maintenance program necessarily includes a regular inspection schedule, with the purpose of identifying maintenance needs and setting priorities for performing maintenance tasks. According to Debo and Reece, there are three types of maintenance: routine, remedial, and capital improvements (Debo and Reece, 1995).

Routine, or preventative, maintenance addresses the activities that happen on a periodic basis, most notably performance standards. They may be driven by the passage of time, instead of by deterioration of the system. It consists of anticipating problems and taking steps to prevent the problems from occurring (such as removing floatable debris upstream of an outlet structure). This type of maintenance generally gets overlooked; however, it needs to become a larger concern for those responsible for the maintenance of stormwater management systems.

Remedial maintenance corrects specific deficiencies in the existing stormwater management system. It concerns making the best use of the existing system, and is not intended to increase its capacity, although correction of any problems will accomplish this task. An important consideration to be made by those responsible for the maintenance of the stormwater system is repair of the system in case of an emergency. This type of maintenance will always be the largest concern because it represents the greatest risk for adverse affects on the responsible party and those downstream.

The purpose of capital improvements is to replace deficient systems with larger or improved designs, which essentially become new systems. Such improvements should include development of a maintenance program for the long-term operation of these new systems. This type of maintenance often gets the most publicity, because of the larger costs and construction projects.

According to the City of Louisville and Jefferson County, Kentucky Metropolitan Sewer District, there are two primary goals of an effective maintenance program:

- Provide, operate and maintain a system of storm water management facilities, controls, criteria, and standards which will mitigate the damaging effects of uncontrolled and unplanned storm water runoff, to improve public health, safety, and welfare, protect property and lives, and maintain and enhance the environment;
 - Establish consistent levels of protection for local and regional collection and transmission systems against flooding for existing and future land development conditions, and to correct existing physical drainage problems.
- (Louisville MSD, 1988)

In summary, a maintenance program consists of a regular inspection schedule that addresses maintenance necessary to ensure that the stormwater management systems performs its intended function for the life of the system.

Benefits of a Successful Maintenance Program

If those responsible for the maintenance of the stormwater management system work to achieve the above goals for the system, other benefits will follow. Some of these benefits are as introduced below.

- One benefit of a successful maintenance program is cleaner water for all. Water is a staple of life that affects all living things, and in many cases a body of water such as a pond, lake, stream, or river is the vital component in the ecosystem. High quality water is a benefit that is important for preserving the health and welfare of the general public, plants and animals.

Pollutants from urbanized areas are washed downstream by stormwater runoff. A matrix showing sources of common pollutants is given as Table 2.1. As a result of stormwater runoff, untreated stormwater has levels of pollutants such as suspended solids, nitrogen, phosphorus, lead, oil/grease, and bacteria that approach levels found in untreated domestic wastewater (Tschantz, 2002). This can be readily seen in Table 2.2, which gives a comparison of typical pollutant levels found in untreated stormwater and domestic wastewater.

Typical values of stormwater runoff are consistently within the range of pollutant levels for domestic wastewater, and exceed these levels in some cases.

- A second benefit is that of erosion control of watercourses. Flowing water is erosive in nature, lifting soil from construction sites, stream banks and streambeds and depositing it downstream. Erosion supplies suspended sediments to the water, decreasing water quality, and also contributing to slope failures, which in can be potentially fatal. Although erosion and sediment control measures should be taken during construction, erosion can occur after construction of the stormwater management system is completed. If water is released from a system at too high of a rate, and stabilization measures are not adequate, then erosion will occur. Proper maintenance of the stormwater management system and its outlets can help prevent this from occurring.
- Another benefit (at least in the cases of ponding and other storage BMPs) is maintaining adequate detention of stormwater runoff, to reduce downstream peak flows and flooding. When properly designed, constructed, and maintained (kept in good working order, with sediment and debris frequently removed), stormwater structures such as ponds, swales, and infiltration

Table 2.1- Sources of Contaminants in Urban Storm Water Runoff

Contaminant	Contaminant Sources
Sediment and Floatables	Streets, lawns, driveways, roads, construction activities, atmospheric deposition, drainage channel erosion
Pesticides and Herbicides	Residential lawns and gardens, roadsides, utility right-of-ways, commercial and industrial landscaped areas, soil wash-off
Organic Materials	Residential lawns and gardens, commercial landscaping, animal wastes
Metals	Automobiles, bridges, atmospheric deposition, industrial areas, soil erosion, corroding metal surfaces, combustion processes
Oil and Grease/Hydrocarbons	Roads, driveways, parking lots, vehicle maintenance areas, gas stations, illicit dumping to storm drains
Bacteria and Viruses	Lawns, roads, leaky sanitary sewer lines, sanitary sewer cross-connections, animal waste, septic systems
Nitrogen and Phosphorus	Lawn fertilizers, atmospheric deposition, automobile exhaust, soil erosion, animal waste, detergents

Source: EPA, 1999

Table 2.2- Typical Characteristics of Different Pollutant Sources

Constituent	Urban Runoff		Domestic Wastewater		
	Separate Sewers		Before Treatment		After Secondary
	Range	Typical	Range	Typical	Typical
COD	200-275	75	250-1000	500	80
TSS	20-2,890	150	100-350	200	20
Total P	0.02-4.30	0.36	4-15	8	2
Total N	0.4-20.0	2	20-85	40	30
Lead	0.01-1.20	0.18	0.02-0.94	0.1	0.05
Copper	0.01-0.40	0.05	0.03-1.19	0.22	0.03
Zinc	0.01-2.90	0.02	0.02-7.68	0.28	0.08
Fecal Coliform per 100 ml	400-50,000		10 ⁶ -10 ⁸		200

Source: EPA, 1999

measures greatly reduce the likelihood of flooding upstream, downstream and on site.

- Increased public safety is another very important benefit. One immediate result of failure of a stormwater management system is flooding. Some results of flooding include softening of structural subgrade and slope failures, which literally allows wash real estate to wash downstream, in addition to potentially being very hazardous. Other hazards exist as well, as in the case of flooded roads. Softening of the subgrade in a road and freeze/thaw conditions can lead to potholes and collapse of the roadbed, which is extremely dangerous—especially during wet conditions when road irregularities cannot be seen. In addition, ponded water on a road surface and the formation of “black ice” often causes cars to lose traction, hydroplane, and become involved in an accident. Flooding of road surfaces cause time delays and traffic problems. These are often results of inadequate maintenance of the stormwater management system. Poorly maintained catch basins, for example, have a tendency to clog and pond water on roadway surfaces, making travel slow and treacherous.
- Another benefit of a successful maintenance program is the demonstration of good public policy. A municipality should always look after the safety and welfare of the community. Inconveniences such and ponding on roadways and frequent flooding of public lands are unsafe and cause political repercussions. It is a wise decision for policy makers to implement maintenance programs for public stormwater management systems to lead the way by setting a good example for all.
- The economic benefits of an effective maintenance program for stormwater management systems outweigh its costs. Often, failure of a stormwater

management system or BMP necessitates the construction of a replacement or emergency measure to handle the stormwater runoff. In most cases, the cost of maintenance is less than the cost of reconstructing a facility. The Stormwater Manager's Resource Center writes, "The expense of maintaining most stormwater BMPs is relatively small compared to original construction costs. However, too frequently, BMP maintenance is not completed, particularly when the BMP is privately owned. Improper maintenance decreases the efficiency of BMPs, and may also detract from the aesthetic qualities of the practice. Proper operation and maintenance language within a stormwater ordinance can ensure that designs facilitate easy maintenance and that regular maintenance activities are completed" (SMRC, 2002). In addition, clean up costs of a failed system can be high, often necessitating the use of heavy construction equipment. Preventative maintenance procedures are generally smaller-scaled operations that cost much less than corrective maintenance procedures. Preventative maintenance is important to ensure the full function and maximum lifespan of the selected BMP.

Properly designed, installed, and maintained controls yield economic benefits. According to the EPA, the nation loses approximately 820,000 acre-feet of water storage capacity each year due to sediment, and that stormwater runoff controls reduces annual dredging and construction costs by \$170-\$510 million (EPA 1997).

- Another benefit is the aesthetics of the stormwater management system, including BMPs. Many BMPs such as detention ponds, constructed wetlands, and rain gardens can enhance a community's environment if they are thoughtfully designed to be a positive part of the site plan and landscaped in a manner such that maintenance is performed during routine grounds maintenance. When a BMP is not maintained, it becomes an eyesore, in addition to having a negative environmental impact on the local community

and environment. Proper operation of stormwater management facilities is vital to ensure the preservation of natural habitat for some plants and animals.

- Increased property values are another benefit. Frequent flooding, turbid water, and poorly maintained stormwater management facilities reduce the value of property. Facilities that are an integral part of local developments and are cared for can not only prevent these problems, but also contribute to increased property values.
- Another benefit is that of community pride. The burden of maintaining many stormwater management facilities rests on the homeowners; however, the duties can be accomplished during community cleanup days. These events help to build camaraderie among neighborhoods and instill a sense of community pride and responsibility. This also affords an opportunity to educate the community of the location, purpose, and importance of the facilities and their maintenance.
- An additional benefit is taking legal responsibility. Poor stormwater management can result in federal, state, and local fines. In addition, the violator will often be subject to pay court-ordered remediation costs. In the Stormwater Management Ordinance of Knox County (Tennessee), the penalty is listed as follows: “Any violations of this ordinance shall be punishable by a fine of not more than one thousand (\$1000.00) dollars for each and every violation. Every day that said violation continues shall be a separate offense. In addition to all other remedies provided by law, Knox County shall have the right to injunctive relief for any violation of this ordinance” (KCDEPW, 2000). Fines will vary throughout the land, depending on the applicable regulation, offense and court.

- A very important benefit of an effective maintenance program is a reduction in the number of lawsuits. Lawsuits are costly for all defendants, including local governments, through higher insurance premiums and attorney fees. If private citizens improperly manage their stormwater, neighboring properties' water quality and quantity are often affected negatively, which in turn leads to lawsuits. Often, such lawsuits will be expansive cases against all property owners in a development, whether or not they are responsible for the problem. An example is found in cases brought forth against neighborhood communities. While all of the properties may not drain to the same watershed, the entire community will be responsible for the maintenance of the stormwater structures. It is important, therefore, to ensure proper maintenance of all common ground facilities.

In order to function properly, a stormwater management system must be maintained.

When the system is cared for, many environmental, economic, and social benefits ensue.

Chapter III – Who is Responsible?

One of the first steps to implementing a stormwater maintenance system is developing ownership of the problems and solutions. The burden of maintaining a stormwater management facility falls on the owner of the facility, whether public, private, or industrial (Tschantz, 2002). Since it has been shown that maintenance of these facilities is crucial, it is wise for public and private entities to develop a maintenance department and/or program to handle these tasks.

Some examples of the responsible parties are as follows:

- Citizens, whether private landowners, or common neighborhood associations;
- Governmental agencies, including federal, state and local. Examples of these include municipal or county public works departments, stormwater utilities, departments of transportation, and departments of parks and recreation;
- Industries and commercial establishments

Many structures are the responsibility of private citizens, while municipalities maintain others. For the most part, structures are maintained by the owner of the parcel on which it stands, and are inspected regularly by the governing authority. Sources of pollutants vary, so types of maintenance will vary as well. Table 3.1 shows a matrix of common maintenance responsibilities.

<i>Table 3.1- Example of BMP Ownership</i>	
Structural BMP	Primary Owners
Detention Pond	Homeowners Association
Culverts	Municipalities
Street Inlets / Catch basins	Municipalities
Ditches	Municipalities
Oil / Water Separators	Commercial / Industrial
Non-Structural BMP	Primary Owners
Street Sweeping	Municipalities / Commercial
Public / Employee Education	Municipalities / Homeowners / Industrial

Citizens

Many citizens are simply not aware that they are responsible for maintenance of their stormwater management and BMP facilities. At the private level, the responsibilities should be made clear at the outset of homeownership, by including it on the deed and in the homeowner organization agreement. Any such agreement should clearly identify responsibilities while providing resources for routine inspection and maintenance of the facilities on their property. The reader is referred to Appendix A for an example of this type of agreement in the Albemarle County, Virginia Stormwater Management/BMP Facilities Agreement. This agreement states that the landowner is responsible for maintaining the BMP facilities, and shall file an inspection report. In addition, the landowner grants the county permission to inspect the facility, and correct deficiencies. Any costs incurred by the county to correct deficiencies are to be billed to the landowner (Albemarle County, 2002). Urbonas and Stahre suggest, “new owners be notified at the time of sale that they are now owners of a local stormwater disposal facility. Such formal notices should also contain the operation and maintenance instructions” (Urbonas and Stahre, 1993).

With the advent of the NPDES Phase II permit, the affected MS4s must maintain their system. As a result, agreements will be bolstered by more proactive stormwater ordinances, such as the one developed by MTAS (MTAS, 2002). The principles are the same, however they are backed by legal and financial consequences as determined by the municipality.

Since the municipality is released from responsibility for maintenance, it is wise for the landowner or homeowner association to provide for continued maintenance of their facilities. This may involve community cleanup days, or a third party contractual maintenance agreement. In addition to preventing corrective maintenance charges from the county, taking a “hands-on” approach to maintenance encourages private citizens to become more aware of the stormwater structures on their property.

This “hands-on” approach is beneficial for the community to understand the function of their stormwater appurtenances; however, individuals and neighborhood organizations should understand their limitations (i.e. which maintenance activities they can safely perform). The Northern Virginia Planning District Commission (NVPDC) notes that safety of the workers, cost of the maintenance operations, and effectiveness of maintenance need to be considered (NVPDC, 2000). The Pennsylvania Association of Conservation Districts, Inc. warns, “Most tasks can be carried out by nontechnical staff or residents quite effectively; however, a program should take precautions to ensure the safety of anyone maintaining the BMP” (PACD, 2002). The NVPDC adds, “While engaging a community or business in routine maintenance is a great way to educate people about the facility’s purpose, it is strongly recommended that a professional landscaping company be hired for more difficult work...Trained personnel may be able to identify problems in their early stages of development when it is most cost effective to make repairs” (NVPDC, 2000).

Public awareness and education is an important aspect of the citizen’s obligation / responsibility for maintenance. Even if the inspection and maintenance work is contracted to another company, “involving the entire community in certain BMP maintenance activities is a cost-effective way to prolong the life-span of the facility and to prevent pollution” (NVPDC, 2000). Public education can be the most effective means of preventative maintenance; an informed citizen is more likely to take the necessary steps to ensure the full function of his stormwater BMP.

Governmental Agencies

All land-owning governmental agencies, whether federal, state, or local, are responsible for the maintenance of the stormwater structures on their property. Various responsible agencies include the departments of transportation, parks and recreation, and local public works. For example, the street department may be responsible for maintaining inlets and catch basins on their rights of way, while the department of public works may have

jurisdiction over the city streets and its appurtenances. Unfortunately, this is a burdensome task for local governments.

In a questionnaire issued by Jacob Chandler in 2001 to 95 Tennessee counties with a 1990 census population of 2500 or greater, funding proved to be a major concern to NPDES Phase II compliance. As Chandler explains, “Over 47% of 91 respondents indicated that they had no idea how the community would fund the NPDES Phase II mandates. Twenty-five percent indicated that a budget/tax increase would be needed, but the problem with a budget/tax increase is that the stormwater funding will come from a general fund, which is not necessarily the most stable funding source. Four percent of the respondents also indicated that they did not know what the Phase II stormwater regulations were” (Chandler, 2001).

Some municipalities have formed separate stormwater utilities to address the various issues associated with the NPDES Phase II program including funding problems. This measure has been taken by many cities of different sizes throughout the country and has been successful.

It is important for separate entities within a watershed to coordinate maintenance efforts to ensure that the entire stormwater management system is in good working order. A typical problem is the case of a stormwater utility employing a thorough maintenance program, only to find that their stormwater runoff is released to a poorly maintained system that fails. Chandler writes, “Local governments must make a policy decision about who is responsible for maintaining the stormwater systems and facilities that are located on public property, but extending onto private property” (Chandler, 2001). In this regard, it is important to understand the extent and level of service, as described by Debo and Reece.

The extent of service is the amount of the drainage system that in some way belongs to the municipality, and the components for which the municipality will provide service

(Debo and Reece, 1995). This should be determined by a survey of boundaries and facilities, and agreed upon by all parties concerned in a timely manner. The function of the system should not be compromised due to contractual disputes. Pyzoha gives two solutions to determining the extent of service. One solution is that the separate entities join as partners in a stormwater program. This will help to distribute the workload and accountability. The other solution is to establish a contractual agreement regarding maintenance (Pyzoha, 1994). This may be a contract involving allocation of each utility's physical resources, or it may involve the hiring of maintenance crews to handle the assorted tasks.

It is important for the local utility to have clearly-cut boundaries of responsibility. Any "gray" areas with respect to maintenance should be sorted immediately. A stormwater conveyance system technically includes all surfaces within a watershed, including rooftops, fields, roads, creeks, and sewers. The utility must list the structures for which it will be responsible. For example, Alley suggests taking responsibility for maintaining all pipes at least 18 inches in diameter, except for smaller pipes downstream from larger structures or known to cause problems (Alley, et. al, 1986). Boundaries of responsibility should only be made after a careful study of the entire drainage system and past complaints has been completed. The importance of each component of a stormwater conveyance system must be understood; it is not acceptable to let a structure go unnoticed and miss needed inspection and maintenance.

The level of service ensures that similarly situated properties are treated in a similar manner (Debo and Reece, 1995). This is not to say that all properties should be treated with the same amount of care; less crucial property with respect to stormwater conveyance, property value, and risk to health and welfare will demand less attention than more valuable property or property where there are more inherent safety risks. The important issue is that the vital components of the stormwater management system are inspected and maintained on a regular basis.

Industrial and Commercial Owners

Industries are also responsible for maintaining the stormwater structures on their property. Typical concerns for industries include budgeting time and sufficient funds to maintain the facilities and educating employees of their responsibilities. Typically, maintenance crews will perform these duties, although employee ownership of the problems and solutions is valuable. For example, educating the employee of responsible disposal of wastes and debris could potentially help to decrease maintenance costs. If oils, trash and debris do not get into the stormwater system, they will not need to be removed later.

Commercial owners must maintain their stormwater management systems and BMPs as well. Runoff collected from their parking lots must be handled and disposed properly. As in the case of industries, employees must be trained of proper disposal of wastes and debris. Managers should schedule sufficient time and resources for parking lots and sidewalks to be swept clean, disposing of trash and debris in trash receptacles, instead of into the storm drain. In addition, owners need to ensure that pollutant controls remain functional and that hazardous wastes are stored away from stormwater facilities and safely disposed.

Other Parties

Independent third parties may take responsibility for maintenance of stormwater management systems and associated BMPs. Many communities have implemented community "Adopt a Stream" or "Adopt a Highway" programs. These programs are beneficial to the public, as they provide free maintenance services to such systems. In addition, they often provide good public relations material for involved parties and promote a sense of responsibility and good stewardship. However, there are some drawbacks.

Legal responsibility must be understood from the outset. It is important to realize that these programs are voluntary and do not relieve the owner of their maintenance responsibility. Organizations that participate in these programs must understand the importance of continued maintenance. Regular inspections must be conducted by the party responsible for maintaining the stormwater management system to ensure that the work is being done. All parties prior to beginning the program must understand responsibility for preventative and corrective maintenance costs.

Often, the owner will hire another company to provide maintenance. A common example of this is a lawn care company providing continued maintenance of a detention pond. Note that the owner is still responsible for continued maintenance, but the lawn care company will be contractually obligated to provide the maintenance. The owner should tell the contractor of the specific duties required to maintain the particular structure.

Another example is through contract arrangements with the manufacturer of BMP products. Practical Best Management of Georgia (PBM), the developer of the CrystalStream[®] oil/water separator, has developed a maintenance agreement to be signed by the owner upon installation of the device (note: Mention of trade names or commercial products does not constitute endorsement or recommendation of same). An example agreement, which is located in Appendix B, involves the inspection schedule, maintenance, and billing. The owner has the option of maintaining the structure, or allowing PBM to perform the inspection and maintenance. In either case, the manufacturer has accounted for maintenance of the structure, and released itself from this liability.

Chapter IV – What Are the Components of an Inspection/Maintenance Program?

The goals of the maintenance program must be firmly established from the outset, and should directly address the issues of stormwater quantity and quality. According to Pyzoha, there are three primary components required to implement a maintenance program. One requirement is the organization of a stormwater maintenance utility. This includes the formation of a stormwater ordinance. The second requirement is an inventory of the stormwater structures in the system. The third requirement is the provision of resources for the program to complete its job. This includes not only provision of monetary funds, but also an inventory of people and equipment needed for maintenance tasks. This will involve formation of program standards (Pyzoha, 1994).

Pyzoha has also suggested a list of steps involved in developing a maintenance program:

- Define the ideal maintenance program
- Determine the available resources, including funds and equipment
- Know distance between ideal and actual program by checking resources and setting priorities
- Set minimum standards to guide and measure capabilities to reach higher objectives
- Place emphasis on where they do most good (Set priority goals)
- Revisit milestones of ultimate program to check if they are still valid
- Make changes if original data and assumptions are incorrect (Pyzoha, 1994)

There are many other steps are involved in this process as well.

Definition of the Ideal Case

Establishing a program should begin with defining the ideal condition with unlimited resources and equal maintenance of all components of the system. High standards, goals and objectives should be set. At the same time, goals should be obtainable, in order for realistic steps to be taken towards achieving the goal. Goals may include no-maintenance based stormwater BMP failures or lowering of pollutant concentration for constituents of concern in local streams.

Stormwater Ordinance

The next step for a municipality towards improving stormwater quality and quantity management is to develop a stormwater ordinance. The purpose of the stormwater ordinance is to set the policies and means of enforcement. According to the Metropolitan Nashville/Davidson County Stormwater Management Manual, their ordinance “established the legal framework for reviewing building permits for stormwater management provisions and for requiring grading permits to control erosion and sedimentation problems.” Further, “these ordinances secured the eligibility of Nashville and Davidson County to participate in the National Flood Insurance Program (NFIP) administered by the Federal Emergency Management Agency (FEMA). Participation in the NFIP provides local property owners with the opportunity to purchase federal flood insurance” (MNDC, 1999).

Establishing the legal framework to manage stormwater is an important step, because it provides a basis upon which regulations can be enforced. MTAS has developed a model stormwater ordinance to aid municipalities in Tennessee in developing stormwater legal structure (MTAS, 2002).

A system to prioritize inspection and maintenance procedures for the stormwater management program is essential in order to effectively allocate resources. For new and

reconstructed systems, an additional component includes the use of maintenance-free designs for stormwater structures. Although this is not a post-construction measure, thoughtful design with consideration of maintenance needs can be a valuable asset to the maintenance program; more maintenance effort can be put forth to other areas.

Stormwater Utility

Forming a stormwater utility is another method to implement a maintenance program. This may be a division of another program, or may be a separate entity. The “Model Stormwater Utility Ordinance” established by MTAS contains a section devoted to the creation of a stormwater utility. According to the ordinance, the utility shall be responsible for the following actions:

- Administer the acquisition, design, construction, maintenance, and operation of the stormwater system
- Administer and enforce the regulations of the stormwater ordinance relating to design, construction, maintenance, and operation
- Advise the municipality’s governing body relating to the stormwater system
- Prepare and revise a comprehensive drainage plan
- Review plans and approve or deny, inspect and accept extensions and connections to the system
- Enforce regulations to protect and maintain water quality and quantity in compliance with water quality standards established by state, regional, and federal agencies
- Annually analyze the cost of services and benefits of the utility. (MTAS, 2002)

Too frequently, fund allocations are not sufficient to fully support the stormwater utility and a comprehensive maintenance plan. Other funding options include grants, loans, plan review fees, and general funds, to name a few. More information on funding can be found in the American Public Works Association's publication, Designing and Implementing an Effective Storm Water Management Program (APWA, 2000).

Many municipalities and counties have generated a separate stormwater utility. Preliminary legal research by the Natural Resources Defense Council (NRDC) found that virtually all states and municipalities have the legal authority to set up such utilities (NRDC, 1999). In a NRDC letter to EPA, it is written, "Storm water utilities are a dedicated and equitable funding source for municipal stormwater programs" (NRDC, 2000). Furthermore, Treadway and Reece write, "A stormwater utility can be seen as an umbrella under which individual communities address their own specific needs in a manner consistent with local problems, priorities, and practices. With the expected needs for increased stormwater management programs, the stability and adequacy of a utility provides a great advantage over other financing methods" (Treadway and Reece, 2000).

Normally, stormwater utility fees are issued to the landowner on either a monthly or annual basis, depending on the amount of impervious area of the property (Chandler, 2001). Typical 1996 stormwater utility fees for selected U.S. cities are given in Figure 4.1. This practice encourages landowners to develop properties with less impervious area. Stormwater credits could be used in this situation to reward BMP implementation that is above the minimum requirements. Revenue received from the utility would cover the municipality's operating costs and inspection costs. These programs have been underway in about 300 cities in at least 20 states, serving populations ranging from 5,000 to 3.5 million (NRDC, 2000). For the most part, these programs have been successful. The NRDC writes, "Revenues generated from utilities can be significant. Bellevue, WA (population 92,000) generated \$7 million in 1990; Austin, TX (population 466,000) generated \$15 million in 1998; Louisville, KY (population 671,000) generated \$16.2 million in 1998...The dedicated and equitable nature is popular among administrators,

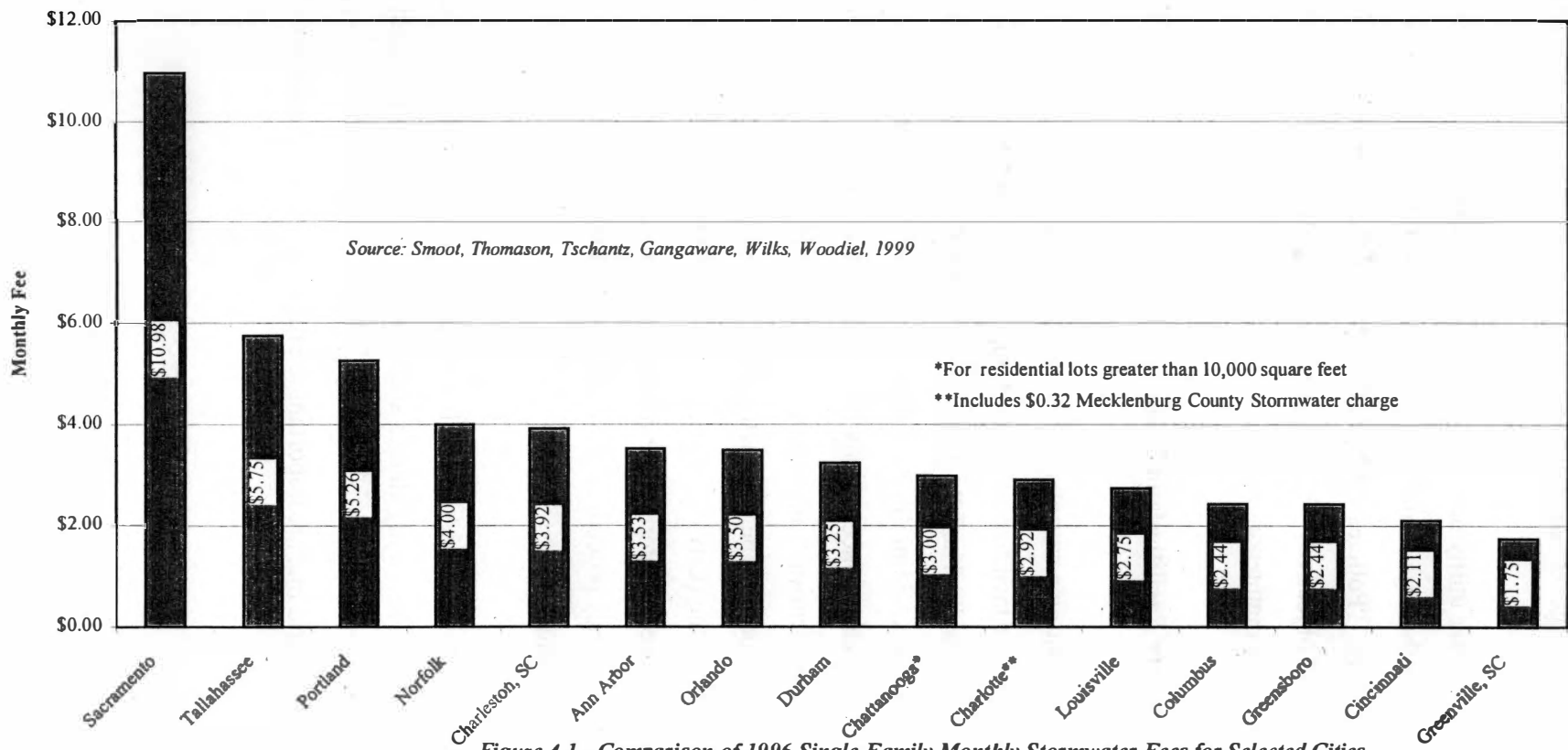


Figure 4.1 - Comparison of 1996 Single Family Monthly Stormwater Fees for Selected Cities

elected officials, and citizens” (NRDC, 2000). The city of Chattanooga, TN (population 156,000) stormwater utility generated about \$8.6 million in 2000/2001 (Fritz, 2002).

The duties of the stormwater utility need to be outlined in a stormwater ordinance. The ordinance should outline the organization of the utility, as well as provide the policies and means of enforcement. “Policies establish the intent of the program; they give the program stated goals and objectives” (Pyzoha, 1994). The goals and objectives will help guide the formation of the maintenance plan.

Inventory of Stormwater Facilities and Resources

The next step to implementing a stormwater maintenance program is gathering an inventory of the stormwater facilities. This is an important step for not only the utilities, but for the community as well. The EPA recognizes this need and has incorporated it as a minimum control measure to aid in illicit discharge detection and elimination (EPA, 2002). While EPA’s mandate concerns only the location of all outfalls and the names of all receiving waters, the stormwater management entity would be wise to inventory each stormwater structure, including type of structure, material, size, location, age, condition, ownership, and priority rating (City of Greensboro, 2002). Other information such as drawings of key elements of the stormwater management system including BMPs, lists of replacement parts, emergency procedures, and important names with telephone numbers for contact would be invaluable.

In addition, the staff, equipment, and materials available for use should be inventoried. According to Robert Alley, inventory should also include “examining all records of complaints and previous drainage studies” (Alley, 1984). In other words, inventory should investigate all criteria that are important to providing good maintenance (Pyzoha, 1994).

Because of NPDES Phase II requirements, inventory programs are underway throughout the country. For example, Greensboro, North Carolina's program "includes three primary components: (1) determination of the location of each structure; (2) collection of structure attributes; and (3) development of a Geographical Information System (GIS) database that includes all of the information on the storm water conveyance system" (City of Greensboro, 2002). There will be many uses for a structure and BMP inventory with maintenance data. A good stormwater management system program can effectively prioritize the maintenance requirements of the stormwater system. Without a detailed inventory, this would be impossible.

Another use of a structure and BMP inventory is the ability to locate the facilities in the system. If a complaint is harbored against a certain structure, the structure or BMP can be easily identified and fixed. Chandler writes, "By having a complete inventory of all stormwater systems and facilities, the maintenance personnel will be able to locate the systems and facilities quickly, which will make the [operations and maintenance] program more productive" (Chandler, 2001).

The use of GIS has been very beneficial to this task. The City of Greensboro was able to inventory over 30,000 stormwater structures and over 300 miles of stormwater pipes, channels, and swales through the use of GIS. (City of Greensboro, 2000) Once inventoried, these structures can be located readily, easing inspection and maintenance operation and scheduling.

While GIS systems are much more affordable than they once were, the cost of these systems may prove to be prohibitive. MTAS notes, "many communities are developing GIS systems jointly, thus sharing in costs and responsibilities" (MTAS, 2000). It is mandatory in this situation, to resolve certain issues such as: how to split the costs, who will have access, what types of data will be included, the priorities of data collection, and whether or not data will be sold to outside entities (MTAS, 2000). Another use of a structure and BMP inventory is for water quality control. In a study performed by

www.evergladesplan.org, water quality control data was used for several reasons: identify the linkages between water quality and ecosystem restoration, identify degraded and at-risk waters, identify and quantify types and sources of pollution, establish recommended pollution load reduction targets, inventory and evaluate the suite of structural and non-structural measures, integrate existing and planned water quality restoration and management programs, recommend additional programs and projects to implement the plan, and to identify funding sources (www.evergladesplan.org, 2002). Stormwater managers will be able to use this data to track water quality and set goals and initiatives for the program.

A detailed structure and BMP inventory is also useful for cost estimate purposes. If the location and condition of the structures are known, then the utility manager can more readily predict when the structures will need to be maintained or replaced.

Allocation of Resources

After taking inventory, the next step in developing an inspection and maintenance program is to compare the utopian system to the available inventory of resources. An important step for those responsible for the stormwater management system is to know the distance between the utopian and actual program. This emphasizes the importance of a thorough inventory of resources, because it aids in setting goals and developing the program in a way that will allow for the realization of the utopian goals. Educated judgment is important in this step, as it will require responsible management and allocation of resources.

Once the inventory of available resources for the maintenance program has been gathered, the maintenance program needs to be developed. The stormwater maintenance program must identify the critical components of the system and set maintenance priorities. The most crucial stormwater structures, ones that have greater potential for loss of life and property damage, should take precedence over others. Most of the time,

this is related to higher population and higher income areas, since there is a greater risk of life and property value in these areas. However, the implementation of a stormwater maintenance program near a low-income area can raise the property value. An effective program will be able to allocate resources in a manner that ensures proper function of the stormwater system, and does the most good for the community. One very important tool for implementing a stormwater maintenance program is an inspection/maintenance priority rating form.

An example inspection/maintenance priority rating form was formed from information given in Urban Stormwater Management and is included in the appendix (APWA, 1981). By using this form, those responsible for allocating program resources will be able to assign a priority value to a structure with respect to four categories: adequacy of design, adequacy of construction, ease of maintenance, and probability of maintenance. In addition, safety concerns and risk of property damage are factors that should weigh heavily into prioritization of inspection and maintenance activities. Because stormwater systems can change over a period of time, given deterioration of existing structures and capital improvements, the forms should be reviewed and revised at least once every five years, in conjunction with the NPDES Phase II permitting period.

In determining an inspection and maintenance priority, the cost of preventative maintenance will be compared to the risk of structure failure. If the maintenance costs are higher than the risk, no action will be taken. Unfortunately, the frequency and duration of a storm is never certain; any structure can fail given a large enough storm, putting surrounding areas in jeopardy.

Setting Standards

Another factor in establishing inspection and maintenance priorities is by setting the program's minimum standards. According to Pyzoha, "[Developing program standards] involves how much can be done in a specified time frame and what amount of people,

equipment, and materials is required” (Pyzoha, 1994). No structure should ever passively be allowed to fail, but realistic standards need to be set in order to keep the system functioning. For example, too much emphasis on a certain detention pond may allow another component or BMP in the watershed to go unnoticed, and consequently fail.

Pyzoha defines two types of standards to be used in this regard: performance standards and conditions standards.

Conditions standards refer to the expected or designated physical condition and functional goals or objectives of the various parts of the drainage system. They are directly related to the ability of the system to fulfill its design purpose (Debo and Reece, 1995). In other words, they relate to the conditions that customers notice and may complain about. For example, if a community anticipates complaints regarding clogging of grate inlets, a conditions standard may be for 95% of all grate inlets must be less than 20% obstructed at any one time (Debo and Reece, 1995).

Performance standards refer to rate of work (in an industrial sense) or production goals or objectives of the various parts of the drainage system (Debo and Reece, 1995). Although they are easy to manage and monitor, there is not always correspondence between meeting the performance objective and actually improving the condition of the system. One example is the performance standard of cleaning 50 catch basins per day. Although the catch basins may be clean, maintenance may be needed more at a couple of detention basins downstream (Debo and Reece, 1995).

Emphasis should be placed on the areas that need the most attention. In practice, many municipalities shift from condition standards to performance standards after experience of inspecting and maintaining the system. If maintenance crews notice that more effort is needed to maintain other components of the system, the stormwater maintenance program should have provisions to reallocate resources to reflect that need (Debo and Reece, 1995). Conditions standards are always important, as they refer to what the citizens see.

However, in order to guarantee that each stormwater structure gets inspected, preventative maintenance relies on performance standards.

Inspector Training

Training of stormwater system inspectors is vital to the success of the system. This practice ensures that the inspection will be carried out thoughtfully and responsibly. The inspector should, at a minimum, be experienced in the design and/or function of stormwater systems and should attend a stormwater structure maintenance seminar held by TDEC or another permitting authority. This will ensure that the stormwater management system will be inspected to a degree that is satisfactory to the permitting authority.

These seminars are in place in many communities for construction site BMPs, but are not as readily available for post construction inspection and maintenance of stormwater management systems with BMPs. It is important that training for post-construction BMP inspectors is implemented; as technologies develop regarding post-construction BMPs, the need for trained, knowledgeable BMP inspectors is magnified.

It is a good idea for an inspector to inspect the same area regularly, as familiarity with the facilities allows one to see what changes have occurred since the last inspection. In addition, this practice will lessen the learning curve of a particular area. In other words, the inspector will already know what to expect, and what duties are typical for a particular structure. However, the inspector should remain objective at each location and note each observed deficiency. A worthy inspector should never get used to the appearance of a BMP and miss a deficient feature.

A detailed record of inspection should be kept by the inspector for each site, with the location and type of deficiencies noted. The program should provide a maintenance and inspection checklist to aid in this function. Examples of these checklists are included in

Appendix C. In addition, the inspector should keep implements handy to correct simple maintenance deficiencies, such as clogged or obstructed inlets. Also, the inspector should be equipped with a camera to take pictures of the site. These photographs can be used to prioritize future inspections, train new inspectors, schedule maintenance equipment/personnel, and visualize the area.

Analyze and Revise the System

The final step in developing an inspection and maintenance program involves analyzing the current situation and taking steps to correct the deficiencies. In addition, the facility inventory and records of maintenance should be kept and updated regularly to ensure an accurate representation of the system. The sample Stormwater Utility Ordinance described earlier in this chapter lists annual analysis of the costs and benefits of the utility as a responsibility. The program should provide procedures to revisit the measurable goals of the NPDES Phase II permit and the ultimate goals of the utopian program to see if the current program is heading in the right direction. Reallocation of maintenance resources will be needed if this is not the case.

In summary, the steps in developing a maintenance program for a stormwater management system are as follows:

- Define the ideal system
- Develop stormwater ordinance
- Develop stormwater framework (utility, agency, bureau, etc.)
- Inventory all stormwater structures and pipes
- Inventory all stormwater personnel, materials, and equipment
- Set conditions and performance standards
- Prioritize inspection and maintenance items

- Develop stormwater inspection staff training program
- Compose inspection and maintenance schedule
- Analyze results and goals of the system.

Some steps will logically precede others; the key point is that these steps are each taken. A utility may find, for example, that the prioritizing of inspection and maintenance items will affect the performance standards. As long as priorities and standards are set, and the utility effectively maintains the system, the order of these steps does not matter.

Chapter V – Maintenance-free Facilities

One solution to the burden of maintenance is to try to anticipate and prevent the problem before it starts, that is, to design “maintenance-free” facilities. A maintenance free facility is one that anticipates potential problems and incorporates defensive design measures to prevent the BMP from becoming dysfunctional. Chandler writes, “Planning for maintenance in the design phase of a project can help reduce the amount and frequency a stormwater system or facility requires to function properly” (Chandler, 2000). This practice will reduce the number of man-hours required for maintenance tasks on these structures, which, in turn, saves money for the utility. “Designing storm water management facilities that are as maintenance free as practical will often result in cost savings that, over the service life of the facility, equal or exceed initial construction cost” (Debo and Reece, 1995). Tschantz has proposed components of maintenance free design:

- Accessibility
- Incorporate measures to aid in maintenance and safety
- Over design structures to ensure adequate performance in case of deficient maintenance
- Discourage unwanted vegetation
- Use of trash and debris control
- Careful design of outlet structures
- Good communication between engineers and maintenance personnel
- Investigate “hot spot” problem areas
- Inspect critical facilities after extreme storm events
- Keep good maintenance records
- Consider redesign at recurring problem areas. (Tschantz, 2002)

Two other maintenance-free criteria to consider involve quality assurance and quality control while constructing the stormwater facility, and planning improvements.

While some of these measures are specific to pond maintenance, the ideas are the same; any item that may eventually become a maintenance issue should be provided in the design. For example, Practical Best Management of Georgia, manufacturer of the CrystalStream Oil/Grit Separator, limits the design of each structure to nine feet maximum depth, because of difficulty maintaining deeper structures (PBM, 2002). The city of Minnesota constructed a natural, open storm water conveyance system because it costs less to build and maintain than a conventional drainage system (NRDC, 2000).

Accessibility

Access to stormwater control structures is of utmost importance. Each structure should be designed to allow for regular care of it. This includes providing enough room for personnel and equipment to physically access the structure, providing adequate access points to the structure, and providing easement rights for proper equipment to serve the structure. Access easements should be provided within maintenance agreements and deeds to provide for routine inspection and maintenance. It is important for the designer to anticipate the potential problems of the structure so he can provide for access. For example, if cleaning a detention pond may require a backhoe, then the easement should provide enough room for the operator to bring and operate the machinery.

Incorporate Measures to Aid in Maintenance and Safety

It is good practice for the designer to design for the worst case. The designer should take into account the safety of maintenance workers when designing BMPs. Tight, confining spaces should be avoided whenever possible. The ability to drain a pond facilitates maintenance and provides a beneficial safety measure. Bank slopes on detention or retention ponds should not be so steep to prevent escape in case someone (especially children) slip or fall into the pond. In such cases, a fence may be warranted. This will also discourage vandalism of the BMP.

Over Design Structures

This measure allows for the over design of a structure. For example, sediment accumulation is to be expected in ponds; by over designing the pond's sediment storage volume, the frequency of removing the sediment can be lessened, especially where future sediment inflow is difficult to predict, such as during development and construction disturbance.

Discourage Unwanted Vegetation

Overgrown vegetation can clog structures and make access difficult. One example is Other vegetation can pose a threat to its stability. For example, deep rooted vegetation such as trees are not ideal for embankments of detention ponds, as decomposition of dead roots can lead to embankment failure.

Use of Trash and Debris Control

Pretreatment of stormwater BMPs can greatly increase its effectiveness. The provision of well-designed trash racks at the inlet of a structure, such as at the outlet structure of both detention and retention ponds, can reduce its potential for clogging. However, it is necessary to clean and maintain the trash racks. If trash racks are not maintained, then the trash rack will be useless. Debris will clog the rack and prevent stormwater from being properly discharged. An example of a trash rack is included as Figure 5.1.

Careful Design of Outlet Structures

Adequate detention of stormwater is reliant on the design of the outlet structure. By designing the structure with care, the potential of flooding will be reduced. This ensures that enough outflow will be allowed to prevent the structure from failing prematurely. Conversely, a properly designed outlet structure will prevent too much discharge from leaving the pond. In addition, with the inclusion of energy dissipators where needed, the potential for downstream erosion will be lessened as well.

A good example of this can be found in Figures 5.2, 5.3, and 5.4. Although these are from an inlet to a detention pond, the principles of energy dissipation are the same. Channel armoring was designed for the inlet of the pond. Because the top of the stone was above the flowing water (Figure 5.1), the stone could not act to resist the shearing forces of the water. As a result, the stormwater runoff eroded the soil beneath the stone armor and caused the channel to fail (Figure 5.3).

Good Communication between Engineers and Maintenance Personnel

Too many designs are constructed with no regard for the people who will be using them. By interviewing maintenance personnel, the design engineer will be able to incorporate items in the design that will reduce maintenance and ease in the maintenance of the facility.

In addition, specific maintenance issues and checklists should be provided to the owner to distribute to maintenance personnel. Urbonas and Stahre write, “As part of the design, provide an operation and maintenance manual to the owner...Such a manual does not need to be complicated. It merely needs to serve as a checklist of things to look for, and to do, on a regular basis” (Urbonas and Stahre, 1993).

Investigate “Hot Spot” Problem Areas

A “Hot Spot” area is any area that will be a critical location for a stormwater control device, is anticipated or expected to be a problem area, or has a history of stormwater management problems. These areas should be carefully surveyed and considered in the design of a stormwater structure. As with any stormwater structure, the design should work to help alleviate the problem, and measures should be taken to solve the other stormwater management issues.

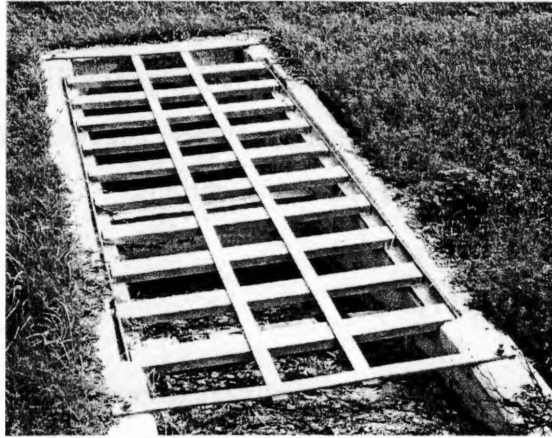


Figure 5.1- Trash Rack Free from Debris



Figure 5.2- Inlet prior to Failure



Figure 5.3- Inlet after Failure



Figure 5.4- View of Inlet from Opposite Side of Pond

Inspect Critical Facilities after Extreme Storm Events

By inspecting other facilities after rain events, the designer will be able to incorporate measures that work into the design of other structures. Likewise, the designer can use working structures as models for other similar situations.

Keep Good Maintenance Records

Accurate maintenance records can become valuable resources in the design of new stormwater management structures. The designer will know what components of that particular design are prone to fail, because detailed records have been kept. The designer can work to implement measures into future designs to combat such failures, and the stormwater manager can anticipate the resources required to maintain current structures.

Consider Redesign at Recurring Problem Areas

Not all BMPs are appropriate in every situation. For example, an infiltration basin may not be suitable for locations with slow-draining soils. The designer should assess current and future situations in selecting a BMP.

Also, a BMP that requires excessive maintenance compared to other BMPs may signify an inadequate design. In this case, redesign may prove to be cost-effective, if recurring maintenance procedures cost more than redesign and reconstruction. A detailed cost analysis should be performed.

Quality Assurance during Construction

The Pennsylvania Handbook of BMPs notes, “BMP maintenance starts by ensuring thorough inspections during construction. Proper construction of the BMP will reduce the maintenance needs of the facility” (PACD, 2002). Urbonas and Stahre note that a complication to this seemingly obvious need is that inspectors “are often not familiar with the technology and functional relationships of such facilities” (Urbonas and Stahre,

1993). Well-drawn sets of construction plans and specifications should include special provisions for the contractor to follow when building stormwater BMPs. The contractor, in turn, needs to take the steps to follow these provisions.

Planning Improvements

Chandler writes, “Developing and following a more effective design, one that incorporates all of the stormwater systems and facilities within a watershed, is designed specifically to be low maintenance and is designed with an eye to future development, is a goal well within reach” (Chandler, 2001). The entire watershed, in effect, is the drainage system. All components should work together to accomplish the same goal of effectively managing stormwater runoff.

“Selling off the BMP”

In a conversation with Dr. J.B. Turnmire of the University of Tennessee, he explained that a way to encourage frequent maintenance and continued care of the BMP is to make the BMP into a desired area. This may include locating a detention pond in an easily seen area, and designing it as a landscaped feature. Another example is designing the pond as a recreation area for a community. It has been found that citizens desire to live in such areas because of the recreational benefits, and as a result, the areas remain well maintained (Turnmire, 2002).

The implementation of an inspection and maintenance program should include the formation of a stormwater utility to operate the program, an inventory of facilities to maintain, an inventory of staff available to perform inspection and maintenance tasks, and a system to prioritize inspection and maintenance operations. Future designs should include maintenance-free design components, which are used as a type of preventative maintenance.

Chapter VI – Constraints to Effective Maintenance

There are many limitations and constraints to be addressed when developing an effective maintenance plan for a stormwater management system. A good understanding of these constraints and limitations will facilitate the identification of cost effective solutions for an effective maintenance program.

Funding

A main reason for not implementing a stormwater maintenance program lies in the lack of an adequately funded program, which has a clear-cut maintenance objective. Pyzoha writes, “Let’s be realistic. Every city, county, or other entity that desires to create a stormwater management program does not have a bottomless pit of money. Make no mistake, money controls the limits and level of detail of what can or will be done” (Pyzoha, 1994). According to a survey distributed by Chandler in 2001 to county and municipal personnel throughout Tennessee, over 60% of the 103 respondents indicated that less than 20% of the annual budget allocated for stormwater and street maintenance is actually spent on stormwater-related maintenance (Chandler, 2001). More often than not, a stormwater maintenance program is seen as non-vital, although most structures require maintenance by design. When the structures fail, however, the community rarely realizes that many of these unfortunate incidents could have been avoided with preventative maintenance.

Priorities

The American Public Works Association correctly points out that “The local public agency having authority for stormwater management typically displays a great deal of interest during the planning, design, and construction stages and for the first several months of operation. The public agency afterwards usually devotes little attention to the project from then on due to the constraints of time, money, and other more urgent matters” (APWA, 1981). Stormwater issues are usually not deemed a priority until they

fail. Local priority of this type of maintenance is often low compared with other local or municipal needs. Pyzoha writes, “Drainage maintenance has never received the attention given to other infrastructure systems” (Pyzoha, 1994). This is partly due to the fact that stormwater occurs only periodically instead of daily like sewage, traffic and other public works responsibilities (Alley, et. al, 1986).

Easements / Access

Another obstacle to a successful stormwater maintenance program is the frequent lack of easements and access. Pyzoha writes, “The concern is that maintenance will not be performed...The alternatives are rights of easement to perform maintenance or a contractual relationship” (Pyzoha, 1994). This should be a key component in the design of any stormwater structure. Access roads should be of adequate size and maintained well enough to allow relative ease of inspection and maintenance.

Personnel

A third reason for a poor stormwater maintenance program is the requirement of a sufficient number of adequately trained personnel to inspect and maintain the stormwater system. Even if all structures were self-cleaning and “maintenance-free”, visual inspections by trained personnel would still be necessary to ensure the function of the system. Goals for a maintenance personnel training program are proposed by Chandler: “The training program should inform the maintenance personnel about stormwater management, potential sources of contaminants, BMPs, SWPPPs (Stormwater Pollution Prevention Plans), why stormwater systems and facilities are necessary, how the systems and facilities work, and what maintenance activities are required to keep stormwater systems and facilities functioning properly” (Chandler, 2001). The importance of a well-educated maintenance staff cannot be overemphasized. Members of the maintenance staff need to be well versed in stormwater issues. This will better prepare them to effectively maintain the system.

Hazardous Work

Another limitation is that labor-intensive “hand methods” (i.e. pulling debris out of an outlet pipe) are often the most effective way to clean a structure. This is not an appealing task and can be quite dangerous. The stormwater maintenance program must provide for educating the maintenance personnel of all occupational hazards and necessary safety precautions. Maintenance free design practices discussed in Chapter V and the frequent cleaning of other structures (at least after every major rainfall) can reduce the amount of debris that builds up around the structures.

Public Awareness

A fourth limitation is the lack of public education and awareness of stormwater issues. Increased public awareness will lead to greater support for the maintenance program, in addition to the adoption of more responsible stormwater practices around the home. For example, the practice of storm drain stenciling has proven effective in reducing pollutant dumping into storm drains.

Public education is vital for industrial sites as well. Each company which has stormwater associated with industrial activities is responsible for obtaining a NPDES permit to discharge runoff to natural watercourses. This includes a stormwater pollution prevention plan (SWPPP). Employees need to be better educated of dumping policies and procedures of their companies.

Enforcement

Another limitation is lack of enforcement of stormwater policies. In a survey conducted in 2001, “It was found that when the private owners fail to responsibly maintain these facilities, almost half of the respondents indicated that no enforcement action was taken against the owner” (Chandler, 2001). The formation of a stormwater ordinance with clear rules, regulations, and penalties for noncompliance will add some muscle to

stormwater maintenance issues. Enforcement should be an ongoing process that will increase as public awareness of stormwater management increases. Pyzoha writes, "Experience has taught that, soon after adoption, there will be a great deal of procedural questions, misunderstanding, lack of knowledge that the program exists, and challenges to the financial and technical / environmental elements of the program. The true merits of the program will depend upon the clarity and strength of the enforcement sections of the ordinance. Clear lines of authority pertaining to the organizational responsibilities and procedural definition is paramount" (Pyzoha, 1994). As the policies gain acceptance, there will be less tolerance for wrongdoing, leading to the levying of fines and other punishment.

Chapter VII – Summary and Conclusions

There were four purposes to this thesis:

- To review the importance of good stormwater system maintenance for stormwater quality and quantity management;
- To identify and summarize the elements of good maintenance protocol and practices;
- To recommend stormwater management facility maintenance guidelines to local officials and public.
- To develop a guide to serve Tennessee municipalities in developing a maintenance program for stormwater management systems.

Stormwater systems, like any facility having purpose, will fail to function effectively if not properly maintained. It is the duty of the owner of the structure, whether governmental or private, to ensure that the system remains in good working order. There are many other reasons for maintaining the structures, including aesthetics, increased public safety, and economic benefits. Another important reason are requirements set forth in EPA's NPDES Phase II program, which will force many municipalities to develop a maintenance program for their stormwater system.

The components of the maintenance program were discussed in detail, including the formation of a stormwater utility to maintain the system, levy fines, and educate the public. An important task for each municipality involves inventorying the entire drainage system, including all structures and available personnel. Another task for the utility will be in setting standards for the system, and ensuring that the entire system is inspected regularly and maintained.

There are many setbacks for implementation of a maintenance plan, such as a lack of funding, personnel and authority, and lack of education on stormwater issues. It is believed that the formation of a separate utility will aid in lessening the drawbacks.

Other issues involving maintenance were discussed, such as the design of “maintenance-free” structures. This practice takes maintenance considerations, such as access, ease of cleaning, and safety of workers into account during design.

The formation of a maintenance program is important, not only to obtain Phase II permitting, but to be a good steward of the stormwater system. Just as a leak in the roof of a house would necessitate the need to fix the problem before the next rainfall, so is the case of a clogged outlet pipe in a detention pond, or clogged street inlet. The timely maintenance is important to the well being of that particular structure, and to the entire system as a whole.

Chapter VIII - Recommendations

As discussed in Chapter V, there are many limitations of a stormwater BMP maintenance program; however, each of these can be resolved with one task in mind: education.

The most vital element to a maintenance program is rooted in public awareness and education. The public needs to know and understand the consequences of not maintaining the stormwater management system. That way, citizens will be more likely to support community actions to help improve stormwater quality. No maintenance program will succeed without having the physical and financial resources required to complete the tasks. Some communities have advocated a separately funded municipal stormwater utility with income contributed by usage fees. If education is not adequate, the general public will not be willing to pay these fees; the utility will not be appreciated, and may be short-lived.

Although some maintenance duties will always necessarily be labor intensive, it is believed that with increased public awareness, the structures will be maintained more frequently, making the maintenance procedures easier. In addition, new technologies and maintenance methods will be developed, as the concept of BMP maintenance becomes better known. This will also undoubtedly aid in the frequency and quality of BMP inspection and maintenance.

One way for the public to become better informed of stormwater issues is the Tennessee Growth Readiness program, which will become available in the spring of 2003. According to a presentation given by Joel Haden of the Tennessee Valley Authority, the program is designed to help communities “Learn how land use decisions affect water quality; comply with new regulatory (Phase II) requirements; and make informed decisions about managing growth” (TGR, 2002). This program was built from practices that have been effective in other communities throughout the nation.

Stormwater policies need to be strict, and they need to be enforced. Ignorance should not be an acceptable excuse for not maintaining stormwater structures. Public education measures should include enforcement and penalty information. Everybody does not feel an obligation to the community or water quality. However, fines and penalties will influence most people. If this is the only means to get the community to pay attention to the important subject of stormwater quality, so be it.

Engineers should keep maintenance measures in mind when designing BMPs, by implementing maintenance free design measures and providing adequate easements and access to the structures. These measures will ease inspection of BMPs and lessen the frequency of maintenance.

It is recommended that municipalities subject to NPDES Phase II regulations take the necessary steps to form a maintenance program, as introduced in Chapter IV. The municipality should take all necessary steps towards realizing the goals of the ideal case.

Communities should develop a stormwater ordinance to establish the legal structure to regulate stormwater runoff. Furthermore, a stormwater utility ordinance is recommended in order to create a stormwater utility. The utility may be part of an existing branch of municipal or county government, or may become a separate entity. For affected MS4s, a local regulatory body is needed to implement measurable goals to comply with EPA's Phase II requirements. For communities not affected by Phase II regulations, the formation of a stormwater utility is still a good idea, since stormwater quality requirements are likely to become more stringent. A community that actively pursues good stormwater management will be better prepared for future regulations.

The municipality should create a detailed inventory of their structures and resources. The high costs pertaining to a GIS database could be shared among cities subject to Phase II permitting, if necessary. In addition, the inventory should be consistently updated.

Furthermore, it is recommended that the inspection schedule, checklists, and priority rating forms included in the Appendix be adopted by stormwater utilities throughout the state. BMP inspectors will use these forms in assessing the maintenance needs of these facilities, setting performance and conditions standards, and setting inspection priorities.

A brief summary of these Appendices is included below.

Appendix A – Stormwater Management/BMP Facilities Agreement from Albemarle County, Virginia

This is a typical example of an agreement developed by a governing agency to ensure the landowner's understanding of their maintenance responsibilities. The agreement removes liability from the municipality in the case of failure, and grants inspection rights to governmental inspectors. Local governments may wish to draw upon this appendix to develop a legally binding agreement with the citizens of their municipality.

Appendix B – CrystalStream[®] Oil/Grit Separator Maintenance Agreement

This is an example of a BMP manufacturer taking responsibility for the owner's implementation of a maintenance program. This ensures that the BMP will perform as intended. The contract is to remain in effect for one year after the installation date, and will automatically renew unless the manufacturer is notified in writing. The owner has the option of supplying maintenance or contracting the manufacturer to provide maintenance.

Appendix C – BMP Maintenance Priority Rating Form

It is unlikely that a stormwater utility will have unlimited resources to frequently inspect and maintain each structure in the system. Once the stormwater utility takes inventory of its stormwater structures, materials, equipment, and personnel, an important task for the

manager is to decide which of these structures will require the most frequent inspection and maintenance. This form, which was adapted from a survey distributed by the American Public Works Association, (APWA, 1981) is a tool that can be used by the stormwater utility to aid in prioritizing the inspection and maintenance duties.

Appendix D – Inspection Checklists and Maintenance Schedules

This appendix includes model checklists to aid in the inspection and maintenance of post-construction stormwater BMPs recommended by TDEC. Each checklist includes common maintenance issues and recommended performance intervals for each type of BMP in the Tennessee Guide to the Selection and Design of Stormwater Best Management Practices. A checklist and schedule should be completed for each BMP in the system to ensure adequate inspection and maintenance. The BMPs represented include:

Retention Pond	Oil/Water Separator
Detention Pond	Filter Strip
Alternative Storage Measures	Filter Bed
Constructed Wetlands	Media Filter
Infiltration BMPs	Bioretention Basin
Porous Pavement	Swale

In some cases, after experience dealing with each BMP, the utility may wish to deviate from the checklists. It is hoped that any new information regarding the maintenance of the BMPs will be made public knowledge through TDEC, publications, seminars, and the World Wide Web.

Appendix E – Sample Inspection Checklist

A sample inspection checklist has been completed for a poorly maintained detention pond to serve as an example of how to use this checklist. Photographs of the site are included to help the user understand common maintenance issues that may be encountered in the field.

Appendix F – Street Sweeping Schedule, Fall 2001 for Arapahoe County, Colorado

This gives an example of a housekeeping procedure that should cycle continuously throughout the year. This schedule could be edited for use in other activities, such as catch basin cleaning, pipe flushing, and channel cleaning. The stormwater utility manager should frequently update schedules.

Many photographs should be taken of the site to assist the manager in understanding the condition of the BMP. These photographs will be valuable in scheduling inspection and maintenance operations, as well in deciding equipment and personnel necessary to complete the job.

An inspector qualification program for post construction BMPs should be developed by the permitting authority to ensure that competent personnel will inspect stormwater BMPs and provide valuable information pertaining to its condition. This program should be mandatory for all inspectors working in the state, and recommended for all engineers that design stormwater BMPs. This program is a vital component to the well being of stormwater maintenance program. It is important for the engineer to understand the maintenance requirements of the designed BMP so he can incorporate maintenance free design practices. It is important for the inspector to understand why he needs to inspect the structure, what to look for, and how to correct deficiencies.

The qualifications of the registered inspector need to be agreed upon by nonpartisan experts throughout the permitting region prior to development of the program. This ensures that municipalities can allocate necessary funding and personnel to obtain required certification. Since some municipalities and communities may wish to contract inspection duties to a private firm, inspection certification will not be solely for government officials.

Some example minimum requirements for post construction BMP inspector certification are experience in the design and/or function of stormwater utilities; and attendance of a stormwater structure maintenance seminar held by the permitting authority. These requirements will ensure that the stormwater utility will be inspected to a degree that is satisfactory to the permitting authority.

Inspection certifications need to be renewable at a rate specified by the permitting authority. Since yearly inspections are recommended on most BMPs, renewed certification should be obtained each year as well. In addition, a competency examination should be required after a pre-determined number of years by the permitting authority.

These seminars are in place in many communities for construction site BMPs, but programs for inspecting post construction BMPs need to be developed. It is especially important to train the inspectors on the function and stormwater control measures when new BMP technologies emerge. A well-educated inspector will be able to more readily note the deficiencies of a system if he knows why it was installed and how it works.

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Appendices

These appendices are intended to aid in the implementation of a stormwater maintenance program. The appendices provide the following information:

Appendix A – Stormwater Management/BMP Facilities Agreement from Albemarle County, Virginia

This is a typical example of an agreement developed by a governing agency to ensure the landowner's understanding of their maintenance responsibilities.

Appendix B – CrystalStream® Oil/Grit Separator Maintenance Agreement

This is an example of a BMP manufacturer taking responsibility for the owner's implementation of a maintenance program. In this case, the owner has the option of supplying maintenance or contracting the manufacturer to provide maintenance.

Appendix C – BMP Maintenance Priority Rating Form

This is a tool that can be used by the stormwater utility to aid in prioritizing the inspection and maintenance duties. It was adapted from a survey distributed by the American Public Works Association. (APWA, 1981)

Appendix D – Inspection Checklists and Maintenance Schedules

This appendix includes model checklists to aid in the inspection and maintenance of post-construction stormwater best management practices (BMPs) recommended by the Tennessee Department of Environment and Conservation (TDEC). Each checklist includes common maintenance issues and recommended performance intervals. The BMPs represented include:

Retention Pond	Oil/Water Separator
Detention Pond	Filter Strip
Alternative Storage Measures	Filter Bed
Constructed Wetlands	Media Filter
Infiltration BMPs	Bioretention Basin
Porous Pavement	Swale

Note: Because of similarity in maintenance procedures, the Infiltration/Percolation Trench, Infiltration Basin, and Underground Drainage System BMP schedules and checklists have been combined.

Appendix E – Sample Inspection Checklist

A sample inspection checklist has been completed for a poorly maintained detention pond. Photographs are included of the site.

Appendix F – Street Sweeping Schedule, Fall 2001 for Arapahoe County, Colorado

This gives an example of a housekeeping procedure that should cycle continuously throughout the year. This schedule could be edited for use in other activities, such as catch basin cleaning, pipe flushing, and channel cleaning.

Appendix A

Stormwater Management/BMP Facilities Agreement from Albemarle County, Virginia

STORMWATER MANAGEMENT/BMP FACILITIES AGREEMENT

Albemarle County, VA

Water Resources Management

(804) 296-5861

THIS AGREEMENT, made and entered into this ____ day of _____, 19____, by and between (Insert Full Name of **Owner**) _____ hereinafter called the "Landowner", and the Board of Supervisors of Albemarle County, Virginia, hereinafter called the "County". WITNESSETH, that WHEREAS, the Landowner is the owner of certain real property described as (Albemarle County tax Map/Parcel Identification Number)

_____ as recorded by deed in the land records of Albemarle County, Virginia, Deed Book _____ Page _____, hereinafter called the "Property". WHEREAS, the Landowner is proceeding to build on and develop the property; and WHEREAS, the Site Plan/Subdivision Plan known as _____, (Name of Plan/Development) hereinafter called the "Plan", which is expressly made a part hereof, as approved or to be approved by the County, provides for detention of stormwater within the confines of the property; and

WHEREAS, the County and the Landowner, its successors and assigns, including any homeowners association, agree that the health, safety, and welfare of the residents of Albemarle County, Virginia, require that on-site stormwater management/BMP facilities be constructed and maintained on the Property; and

WHEREAS, the County requires that on-site stormwater management/BMP facilities as shown on the Plan be constructed and adequately maintained by the Landowner, its successors and assigns, including any homeowners association.

NOW, THEREFORE, in consideration of the foregoing premises, the mutual covenants contained herein, and the following terms and conditions, the parties hereto agree as follows:

1. The on-site stormwater management/BMP facilities shall be constructed by the Landowner, its successors and assigns, in accordance with the plans and specifications identified in the Plan.
2. The Landowner, its successors and assigns, including any homeowners association, shall adequately maintain the stormwater management/BMP facilities. This includes all pipes and channels built to convey stormwater to the facility, as well as all structures, improvements, and vegetation provided to control the quantity and quality of the stormwater. Adequate maintenance is herein defined as good working condition so that these facilities are performing their design functions. The Annual Inspection Report form dated 6/2/92 (or latest date form available) is to be used to establish what good working condition is acceptable to the County.
3. The Landowner, its successors and assigns, shall inspect the stormwater management/BMP facility and submit an inspection report annually. The purpose of the

inspection is to assure safe and proper functioning of the facilities. The inspection shall cover the entire facilities, berms, outlet structure, pond areas, access roads, etc. Deficiencies shall be noted in the inspection report.

4. The Landowner, its successors and assigns, hereby grant permission to the County, its authorized agents and employees, to enter upon the Property and to inspect the stormwater management/BMP facilities whenever the County deems necessary. The purpose of inspection is to follow-up on reported deficiencies and/or to respond to citizen complaints. The County shall provide the Landowner, its successors and assigns, copies of the inspection findings and a directive to commence with the repairs if necessary.

5. In the event the Landowner, its successors and assigns, fails to maintain the stormwater management/BMP facilities in good working condition acceptable to the County, the County may enter upon the Property and take whatever steps necessary to correct deficiencies identified in the inspection report and to charge the costs of such repairs to the Landowner, its successors and assigns. This provision shall not be construed to allow the County to erect any structure of permanent nature on the land of the Landowner outside of the easement for the stormwater management/BMP facilities. It is expressly understood and agreed that the County is under no obligation to routinely maintain or repair said facilities, and in no event shall this Agreement be construed to impose any such obligation on the County.

6. The Landowner, its successors and assigns, will perform the work necessary to keep these facilities in good working order as appropriate. In the event a maintenance schedule for the stormwater management/BMP facilities (including sediment removal) is outlined on the approved plans, the schedule will be followed.

7. In the event the County pursuant to this Agreement, performs work of any nature, or expends any funds in performance of said work for labor, use of equipment, supplies, materials, and the like, the Landowner, its successors and assigns, shall reimburse the County upon demand, within thirty (30) days of receipt thereof for all actual costs incurred by the County hereunder.

8. This Agreement imposes no liability of any kind whatsoever on the County and the Landowner agrees to hold the County harmless from any liability in the event the stormwater management/BMP facilities fail to operate properly.

9. This Agreement shall be recorded among the land records of Albemarle County, Virginia, and shall constitute a covenant running with the land, and shall be binding on the Landowner, its administrators, executors, assigns, heirs and any other successors in interests, including any homeowners association.

WITNESS the following signatures and seals:

Company/Corporation/Partnership Name (Seal)

By: _____

(Type Name)

(Type Title)

STATE OF _____

COUNTY OF _____

The foregoing Agreement was acknowledged before me this ____ day of _____, 20__, by

_____.

NOTARY PUBLIC

My Commission Expires: _____

COUNTY OF ALBEMARLE, VIRGINIA

By: _____

(Type Name)

(Type Title)

STATE OF _____

COUNTY OF _____

The foregoing Agreement was acknowledged before me this ____ day of _____, 19____, by

NOTARY PUBLIC

My Commission Expires: _____

Approved as to Form:

County Attorney Date

Appendix B

CrystalStream® Oil/Grit Separator Maintenance Agreement



Practical Best Management
of Georgia, Incorporated

featuring CrystalStream® technology

CrystalStream® Oil/Grit Separator Maintenance Agreement

Owner:

Project:

**Billing
Address:**

**Installation
Address:**

**Number of
Devices:**

Installation To be agreed upon by
Date: contractor and PBMGa

Scope of Work

This agreement is between the Owner and Practical Best Management of Georgia, Inc. ("PBMGa") for the inspection and maintenance of CrystalStream® Oil/Grit Separator(s) ("CS Device") installed at the above address.

The CS Device traps floatables, sediment, and petroleum products in storm water runoff. PBMGa agrees to remove all of these contaminants on a regular basis to ensure proper operation of the CS Device during rainfall events.

Installation

The CS Device will be installed as soon as possible and practical on the project site to help in maintaining compliance with NPDES requirements.

PBMGa reserves the right to inspect the site for adequate sediment and erosion controls prior to installation. The site development manager is responsible for ensuring that after installation, removal of these controls does not result in excessive debris or silt in the pipe system where it may enter the CS Device. It is the responsibility of the contractor to clean this unit if excessive sediment is allowed to enter the unit. It is also the responsibility of the contractor to clean this unit prior to the site being turned over to the owner.

An accessible, stable roadway must be maintained to allow PBMGa to provide maintenance on these units.

Initial Inspection Schedule

PBMGa agrees to inspect and, if necessary, clean out the CS Device every 30 days for the first 90 days of operation. A flat fee of \$400 per CS Device is charged for these three initial maintenance trips, billed at the time of first inspection.

Ongoing Inspection and Maintenance

PBMGa agrees to inspect and clean out its CS Device every 90 days thereafter unless inspection history proves the need for a more or less frequent maintenance schedule. Any change of schedule will be approved with the Owner. A fee of \$400 per CS Device per maintenance trip will be billed on the date of inspection.

Maintenance is deemed necessary and proper if more than two (2) inches of silt and grit has deposited in the device between maintenance trips. If deposits are found to be less than two (2) inches, the period between maintenance trips will be lengthened by one month, to a maximum of six (6) months between maintenance. A minimum of two (2) maintenance trips per year is required to ensure proper operation of the CS Device.

Maintenance is deemed overdue at any time that four (4) inches of silt and grit has deposited in the bottom of the CS Device. If four (4) inches of silt is encountered during any regular maintenance, the period between maintenance trips will be shortened by one month, to a minimum of two (2) months between maintenance. A maximum of six (6) maintenance trips per year may be required. No change in maintenance frequency will be made without written notification to the owner.

Billing and Fees

Billing for CS Device construction and installation shall be as described in the Sales Agreement accompanying this Maintenance Agreement.

The initial three (3) monthly inspections will be invoiced in total at the time of first inspection, with a 30-day payment due date.

Ongoing inspections will be billed at the time of inspection, with a 30-day payment due date.

Currently debris removed from the CS device is not considered hazardous waste. If the EPA were to change its ruling on this, additional charges would be billed to the Owner for any fees charged by the local landfill for waste disposal of any materials removed from the CS Device.

Monthly late fees of \$25 or 5% of the outstanding total, whichever is greater, will be added to unpaid invoices.

Rate changes will be announced by mail 60 days before going into effect, and Owner may elect to cancel this contract immediately if the new rates are unacceptable.

Duration of Contract

This contract shall remain in effect for one year from the date of installation, and it will automatically renew unless PBMGa is notified in writing at least 30 days prior to the renewal date.

Signed: _____ **Date:** _____
Owner or Authorized Representative

Signed: _____ **Date:** _____
Practical Best Management of Georgia, Inc.

NOTE: Per Gwinnett County regulations, a maintenance agreement must be in effect at all times for active Best Management Practices (BMPs), through a maintenance company approved by Gwinnett County. The Owner must notify the Director of the Gwinnett County Department of Public Utilities of any change in maintenance company or contract conditions to remain in compliance with county water quality regulations.

Appendix C

BMP Maintenance Priority Rating Form

Best Management Practice (BMP) Inspection/Maintenance Priority Rating Form

Type of Structure: _____

Owner: _____

Address of Structure: _____

GIS Location: _____

Community: _____

Year Constructed: _____

Inspector Name: _____

Please rate the BMP with respect to the following categories on a scale of 1-5.

5 = Excellent

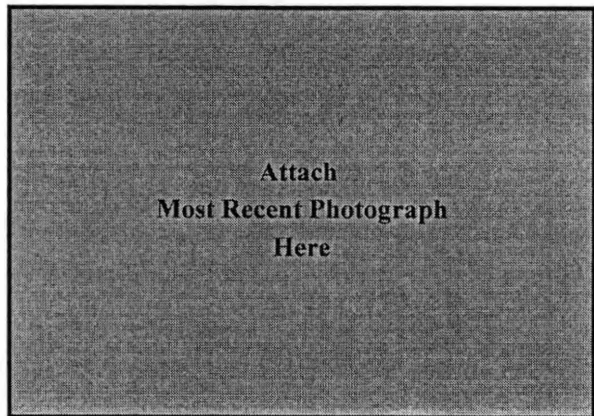
4 = Good

3 = Average

2 = Poor

1 = Not Acceptable

Category	Rating
Adequacy of Design	
Adequacy of Construction	
Ease of Maintenance	
Probability of Maintenance	
Safety	
Property	
Sum	



Use of this Form: This form is designed to aid the stormwater utility manager in scheduling maintenance operations for structural BMPs. Each category (explained below) is to be rated on a scale of 1 to 5. When the tallies are summed, then the BMP with the lowest number has the highest probably of needed maintenance.

Adequacy of Design: Is the BMP properly designed? If properly maintained, would the structure be able to sufficiently accomplish its object?

Adequacy of Construction: Was the structure constructed correctly? Did the contractor display quality workmanship? Can deficiencies in the performance of the BMP be directly attributed to poor construction?

Ease of Maintenance: Is the structure accessible by easement or structural design? Can maintenance equipment easily reach the BMP?

Probability of Maintenance: Does the landowner take a proactive responsibility toward maintenance? Is the BMP difficult by nature to maintain? Is the BMP located in an area that will be seen by others?

Safety: Is there a possibility of death, should the BMP fail?

Property: What is the extent of property damage, should the BMP fail?

Adapted from Urban Stormwater Management by American Public Works Association (APWA, 1981)

Appendix D

Inspection Checklists and Maintenance Schedules

Detention Pond Maintenance Schedule

Owner:

Address of BMP:

Address of Owner:

GIS Location:

Date of Inspection:

Year Constructed:

Inspector Name:

Activity	Schedule
• Clean and remove debris from inlet and outlet structures. • Mow side slopes. • Check condition of safety controls such as signs and fences.	Routine (at least monthly or after major storms)
• If wetland components are included, inspect for invasive vegetation.	Semiannual Inspection
• Inspect for damage, paying particular attention to the control structure. • Check for signs of eutrophic conditions. • Note signs of hydrocarbon build-up, and remove appropriately. • Monitor for sediment accumulation in the facility and forebay. • Examine to ensure that inlet and outlet devices are free of debris and operational. • Check condition and functionality of all control gates pipes, valves or other mechanical devices. • Check stability of side slopes. • Check for erosion of downstream channels.	Annual Inspection
• Repair undercut or eroded areas. • Repair and revegetate eroded areas. • Remove trees from embankments.	As Needed
• Remove sediment buildup.	5 to 7 years, after 50% of the total forebay capacity has been lost, or when service spillway is partially clogged
• Monitor sediment accumulations, and remove sediment when the pool volume has become reduced significantly, or the pond becomes eutrophic.	10 to 20 years or after 25% of the permanent pool volume has been lost

Additional Maintenance Considerations and Requirements

A sediment marker should be located in the forebay to determine when sediment removal is required.

Sediments excavated from stormwater ponds that do not receive runoff from designated hotspots are not considered toxic or hazardous material and can be safely disposed of by either land application or landfilling. Sediment testing may be required prior to sediment disposal when a hotspot land use is present.

Periodic mowing of the pond buffer is only required along maintenance rights-of-way and the embankment. The remaining buffer can be managed as a meadow (mowing every other year) or forest.

Care should be exercised during pond drawdowns to prevent downstream discharge of sediments, anoxic water, or high flows with erosive velocities. The approving jurisdiction should be notified before draining a stormwater pond.

Regular inspection and maintenance is critical to the effective operation of stormwater ponds as designed. Maintenance responsibility for a pond and its buffer should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

Photographs should be taken of the BMP during each inspection.

Adapted from Georgia Stormwater Management Manual by Atlanta Regional Commission (ARC, 2001)

Detention Pond Inspection Checklist

Owner:

Address of BMP:

Address of Owner:

GIS Location:

Date of Inspection:

Year Constructed:

Inspector Name:

A "Yes" answer to any of these items should result in corrective action or a call to a professional engineer.

	Yes	No	N/A	Comments
1. Does the earthen dam's embankment, slopes, side slopes or crest show signs of erosion, settling, cracking, bulging, or other structural deterioration?				
2. Is there embankment seepage or seepage around or under the spillway? (Is the water muddy?)				
3. Are trees or brush present on the embankment?				
4. Are animal burrows present in the embankment?				
5. Do the embankments show signs of significant erosion?				
6. Does the emergency spillway show signs of significant erosion?				
7. Do the side slopes show signs of significant erosion?				
8. Do the inlet or outlet structures show signs of significant erosion?				
9. Does the channelway show signs of significant erosion?				
10. Is there debris or other obstructions blocking the principal outlet or emergency spillway?				
11. Is the outlet pipe damaged or otherwise not functioning properly?				
12. Is there debris or silt clogging the extended detention outlet control?				
13. Is there debris or other obstructions affecting the performance of trash racks or anti-vortex devices?				
14. Is there sufficient sediment accumulation that needs to be removed from the pond?				
15. Do grassed areas require mowing and/or are clippings building up?				
16. Is there debris or trash in the bottom or along the edges of the pond that may clog the outlet structure?				
17. Is water still standing after 48 hours since the last rainfall?				
18. Is there a mosquito problem?				
19. Are there signs of vandalism, especially around and inside the principal outlet, which would impair the safe and effective operation of the pond? This includes the use of the pond area for neighborhood trash and yard waste or filling in the pond area by adjacent homeowners.				
20. Do the fence, gate, lock, signs, or any other safety devices need repair?				

Adapted from Stormwater Management in Tennessee: Guidelines to Preventative Maintenance Practices and Improvements by Jacob S. Chandler (Chandler, 2001)

Retention Pond Maintenance Schedule

Owner:

Address of BMP:

Address of Owner:

GIS Location:

Date of Inspection:

Year Constructed:

Inspector Name:

Activity	Schedule
• Clean and remove debris from inlet and outlet structures. • Mow side slopes. • Check condition of signs and fences (if applicable).	Routine (at least monthly or after major storms)
• If wetland components are included, inspect for invasive vegetation.	Semiannual Inspection
• Inspect for damage, paying particular attention to the control structure. • Check for signs of eutrophic conditions. • Note signs of hydrocarbon build-up, and remove appropriately. • Monitor for sediment accumulation in the facility and forebay. • Examine to ensure that inlet and outlet devices are free of debris and operational. • Check condition and functionality of all control gates, pipes, valves or other mechanical devices. • Check stability of side slopes. • Check for erosion of downstream channels.	Annual Inspection
• Repair undercut or eroded areas. • Repair and revegetate eroded areas. • Remove trees from embankments.	As Needed
• Perform wetland plant management and harvesting.	Annually (if needed)
• Remove sediment from the forebay.	5 to 7 years or after 50% of the total forebay capacity has been lost
• Monitor sediment accumulations, and remove sediment when the pool volume has become reduced significantly, or the pond becomes eutrophic.	10 to 20 years or after 25% of the permanent pool volume has been lost

Additional Maintenance Considerations and Requirements

A sediment marker should be located in the forebay to determine when sediment removal is required.

Sediments excavated from stormwater ponds that do not receive runoff from designated hotspots are not considered toxic or hazardous material and can be safely disposed of by either land application or landfilling. Sediment testing may be required prior to sediment disposal when a hotspot land use is present.

Periodic mowing of the pond buffer is only required along maintenance rights-of-way and the embankment. The remaining buffer can be managed as a meadow (mowing every other year) or forest.

Care should be exercised during pond drawdowns to prevent downstream discharge of sediments, anoxic water, or high flows with erosive velocities. The approving jurisdiction should be notified before draining a stormwater pond.

Regular inspection and maintenance is critical to the effective operation of stormwater ponds as designed. Maintenance responsibility for a pond and its buffer should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

Adapted from Georgia Stormwater Management Manual by Atlanta Regional Commission (ARC, 2001)

Retention Pond Inspection Checklist

Owner: _____

Address of BMP: _____

Address of Owner: _____

GIS Location: _____

Date of Inspection: _____

Year Constructed: _____

Inspector Name: _____

A "Yes" answer to any of these items should result in corrective action or a call to a professional engineer.

	Yes	No	N/A	Comments
1. Does the earthen dam's embankment, slopes, side slopes or crest show signs of settling, cracking, bulging, or other structural deterioration?	_____	_____	_____	
2. Is there embankment seepage or seepage around or under the spillway? (Is the water muddy?)	_____	_____	_____	
3. Are trees or brush present on the embankment?	_____	_____	_____	
4. Are animal burrows present in the embankment?	_____	_____	_____	
5. Do the embankments show signs of significant erosion?	_____	_____	_____	
6. Does the emergency spillway show signs of significant erosion?	_____	_____	_____	
7. Do the side slopes show signs of significant erosion?	_____	_____	_____	
8. Do the inlet or outlet structures show signs of significant erosion?	_____	_____	_____	
9. Does the channelway show signs of significant erosion?	_____	_____	_____	
10. Is there debris or other obstructions blocking the principal outlet or emergency spillway?	_____	_____	_____	
11. Is the outlet pipe damaged or otherwise not functioning properly?	_____	_____	_____	
12. Is there debris or silt clogging the extended detention outlet control?	_____	_____	_____	
13. Is there debris or other obstructions affecting the performance of trash racks or anti-vortex devices?	_____	_____	_____	
14. Is there sufficient sediment accumulation that needs to be removed from the pond?	_____	_____	_____	
15. Do grassed areas require mowing and/or are clippings building up?	_____	_____	_____	
16. Is there debris or trash in or along the edges of the pond that may clog the outlet structure?	_____	_____	_____	
17. Is there water standing in inappropriate areas?	_____	_____	_____	
18. Is there a mosquito problem?	_____	_____	_____	
19. Are there signs of vandalism, especially around and inside the principal outlet, which would impair the safe and effective operation of the pond? This includes the use of the pond area for neighborhood trash and yard waste or filling in the pond area by adjacent homeowners.	_____	_____	_____	
20. Do the fence, gate, lock, or any other safety devices need repair?	_____	_____	_____	

Adapted from Stormwater Management in Tennessee: Guidelines to Preventative Maintenance Practices and Improvements by Jacob S. Chandler (Chandler, 2001)

Alternative Storage Measure Maintenance Schedule*Owner:**Address of BMP:**Address of Owner:**GIS Location:**Date of Inspection:**Year Constructed:**Inspector Name:*

Activity	Schedule
• Remove trash/debris and sediment buildup from ponding area and inlets to minimize outlet clogging and improve aesthetics. • Check condition of signs and fences (if applicable).	Annually and following significant storm events
• Remove sediment buildup. • Repair and revegetate eroded areas. • Inspect access locations • Perform structural repairs to inlets, outlets, vents, and ponding area.	As needed based on inspection
• Perform additional maintenance activities specific to the type of facility.	As required

Additional Maintenance Considerations and Requirements

Specific maintenance activities will be required depending on the type of facility. Such structures should be closely monitored by a licensed professional engineer and / or trained maintenance inspector.

Adapted from Georgia Stormwater Management Manual by Atlanta Regional Commission (ARC, 2001)

Alternative Storage Measure Inspection Checklist

Owner:

Address of BMP:

Address of Owner:

GIS Location:

Date of Inspection:

Year Constructed:

Inspector Name:

A "Yes" answer to any of these items should result in corrective action or a call to a professional engineer.

	Yes	No	N/A	Comments
1. Does the structure show signs of structural deterioration?				
2. Do the inlet or outlet structures show signs of significant erosion?				
3. Does the channelway show signs of significant erosion?				
4. Is there debris or other obstructions blocking the principal outlet or emergency spillway?				
5. Is the outlet pipe damaged or otherwise not functioning properly?				
6. Are the access points readily accessible and safe?				
7. Are the manhole steps in good condition?				
8. Are the vents clear and in good condition?				
9. Are the metal parts rusted and in need of replacement?				
10. Is there sufficient sediment/sludge accumulation that needs to be removed from the structure?				
11. Is there water standing in inappropriate areas?				
12. Is there a mosquito problem?				
13. Are there signs of vandalism, especially around and inside the principal outlet, which would impair the safe and effective operation of the pond? This includes the use of the pond area for neighborhood trash and yard waste or filling in the pond area by adjacent homeowners.				
14. Do the fence, gate, lock, or any other safety devices need repair?				

Adapted from Stormwater Management in Tennessee: Guidelines to Preventative Maintenance Practices and Improvements by Jacob S. Chandler (Chandler, 2001)

Constructed Wetlands Maintenance Schedule

Owner:

Address of BMP:

Address of Owner:

GIS Location:

Date of Inspection:

Year Constructed:

Inspector Name:

Activity	Schedule
• Replace wetland vegetation to maintain at least 50% surface area coverage in wetland plants after the second growing season.	One-Time Activity
• Clean and remove debris from inlet and outlet structures. • Mow side slopes. • Check condition of signs and fences (if applicable).	Frequently (3 to 4 times/year)
• Monitor wetland vegetation and perform replacement planting as necessary.	Semi-annual Inspection (first 3 years)
• Examine stability of the original depth zones and microtopographical features • Inspect for invasive vegetation, and remove where possible. • Inspect for damage to the embankment and inlet/outlet structures. Repair as necessary. • Note signs of hydrocarbon build-up, and remove appropriately. • Monitor for sediment accumulation in the facility and forebay. • Examine to ensure that inlet and outlet devices are free of debris and operational.	Annual Inspection
• Repair undercut or eroded areas.	As Needed
• Harvest wetland plants that have been "choked out" by sediment buildup.	Annually
• Removal of sediment from the forebay.	5 to 7 years or after 50% of the total forebay capacity has been lost
• Monitor sediment accumulations, and remove sediment when the pool volume has become reduced significantly, plants are "choked" with sediment, or the wetland becomes eutrophic.	10 to 20 years or after 25% of the wetland volume has been lost

Additional Maintenance Considerations and Requirements

Maintenance requirements for constructed wetlands are particularly high while vegetation is being established. Monitoring during these first years is crucial to the future success of the wetland as a stormwater structural control. Wetland facilities should be inspected after major storms (greater than 2 inches of rainfall) during the first year of establishment to assess bank stability, erosion damage, flow channelization, and sediment accumulation within the wetland. For the first 3 years, inspections should be conducted at least twice a year.

A sediment marker should be located in the forebay to determine when sediment removal is required.

Accumulated sediments will gradually decrease wetland storage and performance. The effects of sediment deposition can be mitigated by the removal of the sediments.

Sediments excavated from stormwater wetlands that do not receive runoff from designated hotspots are not considered toxic or hazardous material and can be safely disposed of by either land application or landfilling. Sediment testing may be required prior to sediment disposal when a hotspot land use is present. Sediment removed from stormwater wetlands should be disposed of according to an approved erosion and sediment control plan.

Periodic mowing of the wetland buffer is only required along maintenance rights-of-way and the embankment. The remaining buffer can be managed as a meadow (mowing every other year) or forest.

Regular inspection and maintenance is critical to the effective operation of stormwater wetlands as designed. Maintenance responsibility for a wetland facility and its buffer should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

Adapted from Georgia Stormwater Management Manual by Atlanta Regional Commission (ARC, 2001)

Constructed Wetlands Inspection Checklist

Owner: _____

Address of BMP: _____

Address of Owner: _____

GIS Location: _____

Date of Inspection: _____

Year Constructed: _____

Inspector Name: _____

A "Yes" answer to any of these items should result in corrective action or a call to a professional engineer.

	Yes	No	N/A	Comments
1. Does the earthen dam's embankment, slopes, side slopes or crest show signs of settling, cracking, bulging, or other structural deterioration?	_____	_____	_____	
2. Is there embankment seepage or seepage around or under the spillway? (Is the water muddy?)	_____	_____	_____	
3. Are trees or brush present on the embankment?	_____	_____	_____	
4. Are animal burrows present in the embankment?	_____	_____	_____	
5. Do the embankments show signs of significant erosion?	_____	_____	_____	
6. Does the emergency spillway show signs of significant erosion?	_____	_____	_____	
7. Do the side slopes show signs of significant erosion?	_____	_____	_____	
8. Do the inlet or outlet structures show signs of significant erosion?	_____	_____	_____	
9. Does the channelway show signs of significant erosion?	_____	_____	_____	
10. Is there debris or other obstructions blocking the principal outlet or emergency spillway?	_____	_____	_____	
11. Is the outlet pipe damaged or otherwise not functioning properly?	_____	_____	_____	
12. Is there debris or silt clogging the outlet?	_____	_____	_____	
13. Is there debris or other obstructions affecting the performance of trash racks or anti-vortex devices?	_____	_____	_____	
14. Is there sufficient sediment accumulation that needs to be removed from the wetland?	_____	_____	_____	
15. Do grassed areas require mowing and/or are clippings building up?	_____	_____	_____	
16. Are there signs of vandalism, especially around and inside the principal outlet, which would impair the safe and effective operation of the pond? This includes the use of the pond area for neighborhood trash and yard waste or filling in the pond area by adjacent homeowners.	_____	_____	_____	
17. Is there a mosquito problem?	_____	_____	_____	
18. Do the fence, gate, lock, or any other safety devices need repair?	_____	_____	_____	

Adapted from Stormwater Management in Tennessee: Guidelines to Preventative Maintenance Practices and Improvements by Jacob S. Chandler (Chandler, 2001)

Infiltration BMP Maintenance Schedule

Owner:

Address of BMP:

Address of Owner:

GIS Location:

Date of Inspection:

Year Constructed:

Inspector Name:

Activity	Schedule
• Ensure that contributing area, facility and inlets are clear of debris. • Ensure that the contributing area is stabilized. • Remove sediment and oil/grease from pretreatment devices, as well as overflow structures. • Grass filter strips should be mowed and kept trimmed regularly. • Remove grass clippings.	Monthly
• Check observation wells following 3 days of dry weather. Failure to percolate within this time period indicates clogging. • Inspect pretreatment devices and diversion structures for sediment build-up and structural damage. • Remove trees that start to grow in the vicinity of the trench.	Semi-annual Inspection
• Replace pea gravel/topsoil and top surface filter fabric (when clogged). • Dethatch and aerate compacted grass areas.	As needed
• Perform total rehabilitation of the trench to maintain design storage capacity. • Excavate trench walls to expose clean soil.	Upon Failure

Additional Maintenance Considerations and Requirements

A record should be kept of the dewatering time of an infiltration trench to determine if maintenance is necessary.

Removed sediment and media may usually be disposed of in a landfill.

Regular inspection and maintenance is critical to the effective operation of infiltration trench facilities as designed. Maintenance responsibility for a infiltration trench should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

Adapted from Georgia Stormwater Management Manual by Atlanta Regional Commission (ARC, 2001)

Infiltration BNP Inspection Checklist

Owner: _____

Address of BMP: _____

Address of Owner: _____

GIS Location: _____

Date of Inspection: _____

Year Constructed: _____

Inspector Name: _____

A "Yes" answer to any of these items should result in corrective action or a call to a professional engineer.

	Yes	No	N/A	Comments
1. Is there standing water more than 48 hours after the last rainfall?	_____	_____	_____	
2. Is the existing vegetation good condition?	_____	_____	_____	
3. Do grassed areas require mowing and/or are clippings building up?	_____	_____	_____	
4. Is there evidence of heavy vehicular and/or pedestrian traffic?	_____	_____	_____	
5. Are signs in good condition (if applicable)?	_____	_____	_____	
6. Is there any sediment buildup on the infiltration surface?	_____	_____	_____	
7. Is there any signs of excessive erosion in the contributing drainage area?	_____	_____	_____	
8. Are upstream filter strips / inlet filters in good condition and free of trash and debris?	_____	_____	_____	
9. Do the fence, gate, lock, or any other safety devices need repair?	_____	_____	_____	

Adapted from Stormwater Management in Tennessee: Guidelines to Preventative Maintenance Practices and Improvements by Jacob S. Chandler (Chandler, 2001)

Porous Pavement Maintenance Schedule

Owner:

Address of BMP:

Address of Owner:

GIS Location:

Date of Inspection:

Year Constructed:

Inspector Name:

Activity	Schedule
• Initial inspection	Monthly for three months after installation
• Ensure that the porous paver surface is free of sediment • Check to make sure that the system dewaterers between storms.	Monthly
• Ensure that the contributing and adjacent area is stabilized and mowed, with clippings removed. • Ensure that contributing area and porous paver surface are clear of debris.	As needed, based on inspection
• Vacuum sweep porous concrete and paver surface and follow with high pressure hosing on porous concrete to keep pores free of sediment.	Four times a year
• Inspect the surface for deterioration or spalling • Check to make sure that the system dewaterers between storms.	Annually
• Spot clogging can be handled by drilling half-inch holes through the pavement every few feet. • Rehabilitation of the porous concrete and paver system, including the top and base course as needed.	Upon failure

Additional Maintenance Considerations and Requirements

To ensure proper maintenance of porous pavement, a carefully worded maintenance agreement is essential. It should include specific the specific requirements and establish the responsibilities of the property owner and provide for enforcement.

Adapted from Georgia Stormwater Management Manual by Atlanta Regional Commission (ARC, 2001)

Porous Pavement Inspection Checklist

Owner: _____

Address of BMP: _____

Address of Owner: _____

GIS Location: _____

Date of Inspection: _____

Year Constructed: _____

Inspector Name: _____

A "Yes" answer to any of these items should result in corrective action or a call to a professional engineer.

	Yes	No	N/A	Comments
1. Is sediment building up on the surface of the pavers?	_____	_____	_____	
2. Is there evidence of erosion of the media between the pavers ?	_____	_____	_____	
3. Is vegetation growing in the pavement area?	_____	_____	_____	
4. Is there standing water on the pavement for a prolonged period?	_____	_____	_____	
5. Is the area free of trash and debris?	_____	_____	_____	
6. Is the underdrain outlet functioning properly (if applicable)?	_____	_____	_____	
7. Are yard wastes and debris in the contributing drainage area properly disposed?	_____	_____	_____	

Adapted from Stormwater Management in Tennessee: Guidelines to Preventative Maintenance Practices and Improvements by Jacob S. Chandler (Chandler, 2001)

Catch Basin Inserts/Media Filter Maintenance Schedule

Owner:

Address of BMP:

Address of Owner:

GIS Location:

Date of Inspection:

Year Constructed:

Inspector Name:

Activity	Schedule
• Ensure that contributing area, facility, inlets and outlets are clear of debris. • Ensure that the contributing area is stabilized and mowed, with clippings removed. • Remove trash and debris. • Check to ensure that the filter surface is not clogging (also check after moderate and major storms). • Ensure that activities in the drainage area minimize oil/grease and sediment entry to the system. • If permanent water level is present (perimeter sand filter), ensure that the chamber does not leak, and normal pool level is retained.	Monthly
• Check to see that the filter bed is clean of sediment, and the sediment chamber is not more than 50% full or 6 inches, whichever is less, of sediment. Remove sediment as necessary. • Make sure that there is no evidence of deterioration, spalling or cracking of concrete. • Inspect grates (perimeter sand filter). • Inspect inlets, outlets and overflow spillway to ensure good condition and no evidence of erosion. • Repair or replace any damaged structural parts. • Stabilize any eroded areas. • Ensure that flow is not bypassing the facility. • Ensure that no noticeable odors are detected outside the facility.	Annually
• If filter bed is clogged or partially clogged, manual manipulation of the surface layer of sand may be required. Remove the top few inches of sand, roto-till or otherwise cultivate the surface, and replace media with sand meeting the design specifications. • Replace any filter fabric that has become clogged.	As needed

Additional Maintenance Considerations and Requirements

A record should be kept of the dewatering time for a sand filter to determine if maintenance is necessary.

When the filtering capacity of the sand filter facility diminishes substantially (i.e., when water ponds on the surface of the filter bed for more than 48 hours), then the top layers of the filter media (topsoil and 2 to 3 inches of sand) will need to be removed and replaced. This will typically need to be done every 3 to 5 years for low sediment applications, more often for areas of high sediment yield or high oil and grease.

Removed sediment and media may usually be disposed of in a landfill.

Regular inspection and maintenance is critical to the effective operation of sand filter facilities as designed. Maintenance responsibility for a sand filter system should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

Adapted from Georgia Stormwater Management Manual by Atlanta Regional Commission (ARC, 2001)

Catch Basin Inserts/Media Filter Inspection Checklist

Owner: _____

Address of BMP: _____

Address of Owner: _____

GIS Location: _____

Date of Inspection: _____

Year Constructed: _____

Inspector Name: _____

A "Yes" answer to any of these items should result in corrective action or a call to a professional engineer.

	Yes	No	N/A	Comments
1. Does the earthen dam's embankment, slopes, side slopes or crest show signs of settling, cracking, bulging, or other structural deterioration?	_____	_____	_____	
2. Is there embankment seepage or seepage around or under the spillway? (Is the water muddy?)	_____	_____	_____	
3. Are trees or brush present on the embankment?	_____	_____	_____	
4. Are animal burrows present in the embankment?	_____	_____	_____	
5. Do the embankments show signs of significant erosion?	_____	_____	_____	
6. Does the emergency spillway show signs of significant erosion?	_____	_____	_____	
7. Do the side slopes show signs of significant erosion?	_____	_____	_____	
8. Do the inlet or outlet structures show signs of significant erosion?	_____	_____	_____	
9. Does the channelway show signs of significant erosion?	_____	_____	_____	
10. Is there debris or other obstructions blocking the principal outlet or emergency spillway?	_____	_____	_____	
11. Is the outlet pipe damaged or otherwise not functioning properly?	_____	_____	_____	
12. Is there debris or silt clogging the extended detention outlet control?	_____	_____	_____	
13. Is there debris or other obstructions affecting the performance of trash racks or anti-vortex devices?	_____	_____	_____	
14. Is there sufficient sediment accumulation that needs to be removed from the pond?	_____	_____	_____	
15. Do grassed areas require mowing and/or are clippings building up?	_____	_____	_____	
16. Is there water standing in inappropriate areas?	_____	_____	_____	
17. Are there signs of vandalism, especially around and inside the principal outlet, which would impair the safe and effective operation of the pond? This includes the use of the pond area for neighborhood trash and yard waste or filling in the pond area by adjacent homeowners.	_____	_____	_____	
18. Do the fence, gate, lock, or any other safety devices need repair?	_____	_____	_____	

Adapted from Stormwater Management in Tennessee: Guidelines to Preventative Maintenance Practices and Improvements by Jacob S. Chandler (Chandler, 2001)

Oil/Water Separator Maintenance Schedule

Owner:

Address of BMP:

Address of Owner:

GIS Location:

Date of Inspection:

Year Constructed:

Inspector Name:

Activity	Schedule
• Inspect the gravity separator unit.	Regularly (quarterly)
• Clean out sediment, oil and grease, and floatables, using catch basin cleaning equipment (vacuum pumps). Manual removal of pollutants may be necessary.	As Needed

Additional Maintenance Considerations and Requirements

Additional maintenance requirements for a proprietary system should be obtained from the manufacturer.

Failure to provide adequate inspection and maintenance can result in the resuspension of accumulated solids. Frequency of inspection and maintenance is dependent on land use, climatological conditions, and the design of gravity separator.

Proper disposal of oil, solids and floatables removed from the gravity separator must be ensured.

Specific maintenance activities will be required depending on the type of facility. Such structures should be closely monitored by a licensed professional engineer and / or trained maintenance inspector.

Adapted from Georgia Stormwater Management Manual by Atlanta Regional Commission (ARC, 2001)

Oil/Water Separator Inspection Checklist

Owner: _____

Address of BMP: _____

Address of Owner: _____

GIS Location: _____

Date of Inspection: _____

Year Constructed: _____

Inspector Name: _____

A "Yes" answer to any of these items should result in corrective action or a call to a professional engineer.

	Yes	No	N/A	Comments
1. Is the structure easily and readily accessible?	_____	_____	_____	
2. Is there standing water in inappropriate areas?	_____	_____	_____	
3. Is there sediment buildup in the structure?	_____	_____	_____	
4. Is there silt, trash or debris in the inlet?	_____	_____	_____	
5. Are there signs of structural deterioration of the structure?	_____	_____	_____	
6. Is the outlet clogged?	_____	_____	_____	
7. Do upstream grassed areas require mowing and/or are clippings building up?	_____	_____	_____	
8. Are there signs of vandalism, especially around and inside the principal outlet, which would impair the safe and effective operation of the structure? This includes the use of the pond area for neighborhood trash and yard waste.	_____	_____	_____	
9. Do the fence, gate, lock, or any other safety devices need repair?	_____	_____	_____	

Adapted from Stormwater Management in Tennessee: Guidelines to Preventative Maintenance Practices and Improvements by Jacob S. Chandler (Chandler, 2001)

Filter and Buffer Strip Maintenance Schedule

Owner:

Address of BMP:

Address of Owner:

GIS Location:

Date of Inspection:

Year Constructed:

Inspector Name:

Activity	Schedule
• Mow grass to maintain a 2 to 4 inch height.	Regularly (frequently)
• Inspect pea gravel diaphragm for clogging and remove built-up • Inspect vegetation for rills and gullies and correct. Seed or sod bare earth. • Inspect to ensure that grass has established. If not, replace with an alternative species.	Annual Inspection (Semi-annual first year)

Additional Maintenance Considerations and Requirements

Filter strips require similar maintenance to other vegetative practices. Maintenance is very important for filter strips, particularly in terms of ensuring that flow does not short circuit the practice.

Adapted from Georgia Stormwater Management Manual by Atlanta Regional Commission (ARC, 2001)

Filter and Buffer Strip Inspection Checklist

Owner: _____

Address of BMP: _____

Address of Owner: _____

GIS Location: _____

Date of Inspection: _____

Year Constructed: _____

Inspector Name: _____

A "Yes" answer to any of these items should result in corrective action or a call to a professional engineer.

	Yes	No	N/A	Comments
1. Do grassed areas require mowing and/or are clippings building up?	_____	_____	_____	
2. Is there debris or trash accumulating on the filter strip?	_____	_____	_____	
3. Is there evidence of sediment buildup on the filter strip?	_____	_____	_____	
4. Is there evidence of excessive erosion and sedimentation in the contributing drainage area?	_____	_____	_____	
5. Is the vegetation in good condition?	_____	_____	_____	
6. Is there water standing in inappropriate areas?	_____	_____	_____	

Adapted from Stormwater Management in Tennessee: Guidelines to Preventative Maintenance Practices and Improvements by Jacob S. Chandler (Chandler, 2001)

Filter/Adsorption Bed Maintenance Schedule

Owner:

Address of BMP:

Address of Owner:

GIS Location:

Date of Inspection:

Year Constructed:

Inspector Name:

Activity	Schedule
• Monitor water level in sand filter chamber.	Quarterly and following large storm events
• Sedimentation chamber should be cleaned out when the sediment depth reaches 12 inches.	As needed
• Remove accumulated oil and floatables in sedimentation chamber.	As needed, (typically every 6 months)

Adapted from Georgia Stormwater Management Manual by Atlanta Regional Commission (ARC, 2001)

Filter/Adsorption Bed Inspection Checklist

Owner: _____

Address of BMP: _____

Address of Owner: _____

GIS Location: _____

Date of Inspection: _____

Year Constructed: _____

Inspector Name: _____

A "Yes" answer to any of these items should result in corrective action or a call to a professional engineer.

	Yes	No	N/A	Comments
1. Do grassed areas require mowing and/or are clippings building up?	_____	_____	_____	
2. Is there debris or trash accumulating on the filter strip?	_____	_____	_____	
3. Is there evidence of sediment buildup on the filter strip?	_____	_____	_____	
4. Is there evidence of excessive erosion and sedimentation in the contributing drainage area?	_____	_____	_____	
5. Is the vegetation in good condition?	_____	_____	_____	
6. Is there water standing in inappropriate areas?	_____	_____	_____	
7. Is there debris, trash, oils and sediment accumulating in the sedimentation chamber?	_____	_____	_____	

Adapted from Stormwater Management in Tennessee: Guidelines to Preventative Maintenance Practices and Improvements by Jacob S. Chandler (Chandler, 2001)

Bioretention Basin (Rain Garden) Maintenance Schedule

Owner:

Address of BMP:

Address of Owner:

GIS Location:

Date of Inspection:

Year Constructed:

Inspector Name:

Activity	Schedule
• Pruning and weeding to maintain appearance. • Mulch replacement when erosion is evident. • Remove trash and debris.	As needed
• Inspect inflow points for clogging (off-line systems). Remove any sediment. • Inspect filter strip/grass channel for erosion or gullyng. Re-seed or sod as necessary. • Trees and shrubs should be inspected to evaluate their health and remove any dead or severely diseased vegetation.	Semi-annually
• The planting soils should be tested for pH to establish acidic levels. If the pH is below 5.2, limestone should be applied. If the pH is above 7.0 to 8.0, then iron sulfate plus sulfur can be added to reduce the pH.	Annually
• Replace mulch over the entire area. • Replace pea gravel diaphragm if warranted.	2 to 3 years

Additional Maintenance Considerations and Requirements

The surface of the ponding area may become clogged with fine sediment over time. Core aeration or cultivating of unvegetated areas may be required to ensure adequate filtration.

Regular inspection and maintenance is critical to the effective operation of bioretention facilities as designed. Maintenance responsibility for a bioretention area should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

Adapted from Georgia Stormwater Management Manual by Atlanta Regional Commission (ARC, 2001)

Bioretention Basin (Rain Garden) Inspection Checklist

Owner: _____

Address of BMP: _____

Address of Owner: _____

GIS Location: _____

Date of Inspection: _____

Year Constructed: _____

Inspector Name: _____

A "Yes" answer to any of these items should result in corrective action or a call to a professional engineer.

	Yes	No	N/A	Comments
1. Is vegetation healthy and in good condition?	_____	_____	_____	
2. Is there water standing in inappropriate areas?	_____	_____	_____	
3. Is there trash, sediment, or debris accumulating in the basin?	_____	_____	_____	
4. Is invasive vegetation present?	_____	_____	_____	
5. Do the embankments show signs of significant erosion?	_____	_____	_____	
6. Does the emergency spillway show signs of significant erosion?	_____	_____	_____	
7. Do the side slopes show signs of significant erosion?	_____	_____	_____	
8. Do the inlet or outlet structures show signs of significant erosion?	_____	_____	_____	
9. Does the channelway show signs of significant erosion?	_____	_____	_____	
10. Is there debris or other obstructions blocking the principal outlet or emergency spillway?	_____	_____	_____	
11. Is the outlet pipe damaged or otherwise not functioning properly?	_____	_____	_____	
12. Do grassed areas require mowing and/or are clippings building up?	_____	_____	_____	
13. Does vegetation need pruning or thinning?	_____	_____	_____	
14. Are there signs of vandalism, especially around and inside the principal outlet, which would impair the safe and effective operation of the structure? This includes the use of the area for neighborhood trash and yard waste.	_____	_____	_____	
15. Do the fence, gate, lock, or any other safety devices need repair?	_____	_____	_____	

Adapted from Stormwater Management in Tennessee: Guidelines to Preventative Maintenance Practices and Improvements by Jacob S. Chandler (Chandler, 2001)

Swale Maintenance Schedule

Owner:

Address of BMP:

Address of Owner:

GIS Location:

Date of Inspection:

Year Constructed:

Inspector Name:

Activity	Schedule
• For dry swales, mow grass to maintain a height of 4 to 6 inches. Remove grass clippings.	As needed (frequent/seasonally)
• Inspect grass along side slopes for erosion and formation of rills or gullies and correct. • Remove trash and debris accumulated in the channel and inflow forebay. • Inspect and correct erosion problems in the sand/soil bed of dry swales. • Based on inspection, plant an alternative grass species if the original grass cover has not been successfully established. • Remove woody vegetation and stabilize and revegetate side and bottom areas. • Replant wetland species (for wet swale) if not sufficiently established. • Inspect pea gravel diaphragm for clogging and correct the problem.	Annually (Semi-annually the first year)
• Roto-till or cultivate the surface of the sand/soil bed of dry swales if the swale does not draw down within 48 hours. • Remove sediment build-up within the bottom of the swale once it has accumulated to 25% of the original design volume.	As needed

Additional Maintenance Considerations and Requirements

Regular inspection and maintenance is critical to the effective operation of an enhanced swale system as designed. Maintenance responsibility for a dry or wet swale should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

Adapted from Georgia Stormwater Management Manual by Atlanta Regional Commission (ARC, 2001)

Swale Inspection Checklist

Owner: _____

Address of BMP: _____

Address of Owner: _____

GIS Location: _____

Date of Inspection: _____

Year Constructed: _____

Inspector Name: _____

A "Yes" answer to any of these items should result in corrective action or a call to a professional engineer.

	Yes	No	N/A	Comments
1. Are trees or brush present within the swale?	_____	_____	_____	
2. Does the side slopes show signs of significant erosion?	_____	_____	_____	
3. Does the channelway show signs of significant erosion?	_____	_____	_____	
4. Is there trash, debris or sediment buildup in the drainage way?	_____	_____	_____	
5. Is there evidence of excessive erosion and sedimentation in the contributing drainage area?	_____	_____	_____	
6. Is there a mosquito problem?	_____	_____	_____	
7. Is there an odor problem?	_____	_____	_____	

Adapted from Stormwater Management in Tennessee: Guidelines to Preventative Maintenance Practices and Improvements by Jacob S. Chandler (Chandler, 2001)

Appendix E

Sample Inspection Checklist

Appendix E – Sample Inspection Checklist

A poorly maintained detention pond was chosen for the completion of a sample inspection checklist, to demonstrate the effects of a poor maintenance program. Photographs of the site from various vantage points follow.

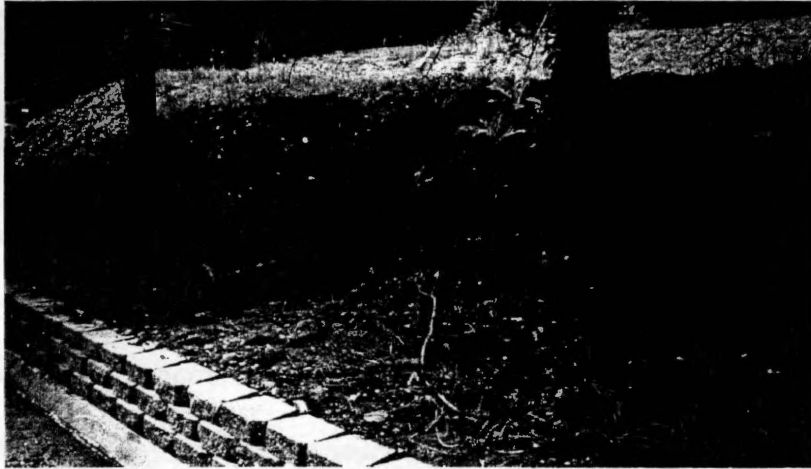


Figure E.1- Embankment of detention pond. Notice the trees on the embankment and large gully formation. The gully formation suggests overtopping due to poor maintenance and/or improper design. Lack of ground cover and deposited soil show significant erosion, which needs to be corrected.



Figure E.2- Longitudinal view of pond. Notice the large amount of trash and debris in and around the pond. The outlet control structure can be seen in the foreground. Standing water would suggest clogging in the outlet control structure, if 48 to 72 hours have passed since the last rainfall. In the distance, notice the erosive action on the inlet channel.

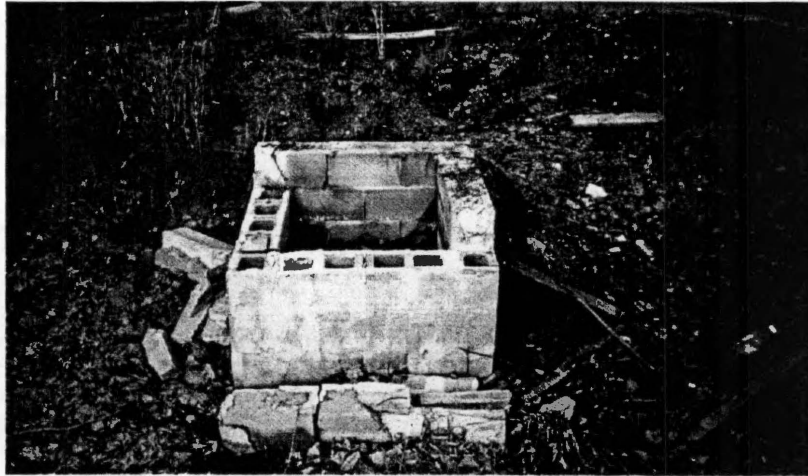


Figure E.3- View of the outlet structure. In addition to the structural damage to the structure, note the trash build-up on the inlet grate and around the structure. A significant amount of deterioration has occurred on the embankment around the structure.

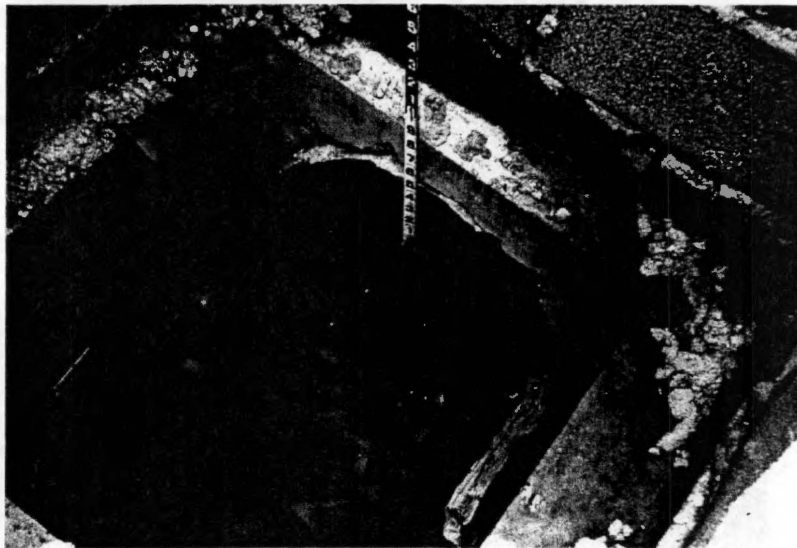


Figure E.4- View inside the outlet structure. Notice that sediment has built up over one-half of the depth of the pipe. This not only adds to the likelihood of clogging during a storm event, but also will transport much of this sediment out of the structure and into receiving streams.

Analysis

See the sample inspection checklist, Figure E.5. Most of the items on the checklist were deemed unacceptable. The “Comments” column is intended to briefly describe the nature of the problem to aid in the procurement of the appropriate tools to fix the problem. If possible, the inspector should take as many photographs as possible of the site.

Detention Pond Inspection Checklist

Owner:

Address of BMP:

GIS Location:

Date of Inspection:

Year Constructed:

Inspector Name:

Address of Owner:

A "Yes" answer to any of these items should result in corrective action or a call to a professional engineer.

Yes No N/A Comments

1. Does the earthen dam's embankment, slopes, side slopes or crest show signs of erosion, settling, cracking, bulging, or other structural deterioration?

✓ ☐ ☐ Gully formation on slopes

2. Is there embankment seepage or seepage around or under the spillway? (Is the water muddy?)

✓ ☐ ☐

3. Are trees or brush present on the embankment?

✓ ☐ ☐ 2 lg. trees & brush

4. Are animal burrows present in the embankment?

☐ ✓ ☐

5. Do the embankments show signs of significant erosion?

✓ ☐ ☐

6. Does the emergency spillway show signs of significant erosion?

☐ ☐ ✓ No emerg. spillway; Dam overtopped

7. Do the side slopes show signs of significant erosion?

✓ ☐ ☐

8. Do the inlet or outlet structures show signs of significant erosion?

✓ ☐ ☐ Deterioration around struct.

9. Does the channelway show signs of significant erosion?

✓ ☐ ☐ Inlet channel eroded

10. Is there debris or other obstructions blocking the principal outlet or emergency spillway?

✓ ☐ ☐ Trash on trash rack

11. Is the outlet pipe damaged or otherwise not functioning properly?

✓ ☐ ☐ Pipe 1/2 full w/ sediment

12. Is there debris or silt clogging the extended detention outlet control?

✓ ☐ ☐

13. Is there debris or other obstructions affecting the performance of trash racks or anti-vortex devices?

✓ ☐ ☐

14. Is there sufficient sediment accumulation that needs to be removed from the pond?

✓ ☐ ☐

15. Do grassed areas require mowing and/or are clippings building up?

☐ ✓ ☐

16. Is there debris or trash in the bottom or along the edges of the pond that may clog the outlet structure?

✓ ☐ ☐

17. Is water still standing after 48 hours since the last rainfall?

✓ ☐ ☐

18. Is there a mosquito problem?

☐ ✓ ☐

19. Are there signs of vandalism, especially around and inside the principal outlet, which would impair the safe and effective operation of the pond? This includes the use of the pond area for neighborhood trash and yard waste or filling in the pond area by adjacent homeowners.

☐ ☐ ✓ ☐

20. Do the fence, gate, lock, signs, or any other safety devices need repair?

☐ ☐ ☐ ✓

Adapted from Stormwater Management in Tennessee: Guidelines to Preventative Maintenance Practices and Improvements by Jacob S. Chandler (Chandler, 2001)

Figure E.5- Sample Inspection Checklist

Appendix F

Street Sweeping Schedule, Fall 2001 for Arapahoe County, Colorado

STREET SWEEPING SCHEDULE FALL 2001			
Order	Section Number	Subdivision Location	Week
1	1971-32	Loretto Heights	10-Sep
2	2077-19/30	Normandy Estates, Columbine Manor	17-Sep
3	2077-35	Cherrywood Village, Four Lakes, The Highlands, Arapahoe Highlands	24-Sep
4	2077-15/22/23/26/27	Brookridge, Southglenn, Southwind, Broadway Estates, Orchard Manor, Southwood Cherry Wood Village	01-Oct
5	2077-24	Dreamhouse Acres, Cherry Hills Manor, Strawberry Hill	08-Oct
6	2077-25	Cherry Knolls, The Knolls	15-Oct
7	2077-36	Highland 460, Bristol Cove, Forest Park	22-Oct
8	2075-30	Nob Hill, Ridgeview Hills South, Liberty Hills, Heritage Greens, Homestead Farms II	29-Oct
9	2075-19	Ridgeview Hills North, Heritage	05-Nov
10	2075-20	Palos Verdes, Cherry Park, Heritage Place, Madison Park	12-Nov
11	2075-29	Homestead, Homestead in the	19-Nov
12	2075-32	Foxridge, Fosridge West, The Ridge Foxridge, Homestead Farms II	26-Nov
13	2075-33	Willow Creek	03-Dec
14	2075-28	Walnut Hills, Hunters Hill	10-Dec
15	2075-22	Arapahoe Lakes, Cherry Farms, Orchard Gate	17-Dec
16	2075-14/15/23	Hills of Cherry Creek, Cherry Creek Vista	24-Dec
17	2073-	Algonquin Acres, Valley Club Estates, Piney Creek Ranches, Antelope, Chapparal, Chenango, Saddle Rock Ranches, Greenfield, Stage Run	31-Dec
18	2073-	Cherry Creek Rancho, Spring Creek, Parkview Greens, Parksborough, Parkview Ridge, Foxhill, Smokey Ridge, Smokey Hill 400, Piney Creek, Piney Creek East, Jackson Farms, Hills of Piney Creek	07-Jan-02
19	1973-	Huntington Estates, Holly Hills (NE, NW, & SE), Cherry Hills Heights, Yorkshire Estates	14-Jan-02

All schedules are tentative and subject to weather. Business parks are last on the sweeping schedule. Sweeping dates could be earlier if gains can be realized in smaller sections.

Adapted from Arapahoe County, Colorado, 2001. "Street Sweeping Schedule Fall 2001." Accessed from www.co.arapahoe.co.us – 11/10/02.

Vita

Robert Guffee Morton was born in Memphis, Tennessee on April 17, 1974. He graduated high school from Brentwood Academy in May 1992. From there, he attended Tulane University and Samford University prior to obtaining his Bachelor of Science degree in Civil Engineering from the University of Tennessee, Knoxville in the Spring of 1998.

Mr. Morton then worked in Atlanta, Georgia for Delon Hampton and Associates, Chartered, where he served as a civil engineer for such projects as the Georgia World Congress Center, South Fork Peachtree Creek Relief Sewer, and other major municipal projects.

Mr. Morton enrolled for his Master's Degree in Environmental Engineering at the University of Tennessee, Knoxville in August 2001. In addition to his studies, he worked part time as a consultant for SITE, Incorporated, assisted in the composition of the Tennessee Guide to the Selection and Design of Stormwater Best Management Practices with the Tennessee Water Resources Research Center, and served as a Graduate Teaching Assistant for the Civil Engineering 390 Hydraulics Laboratory.

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