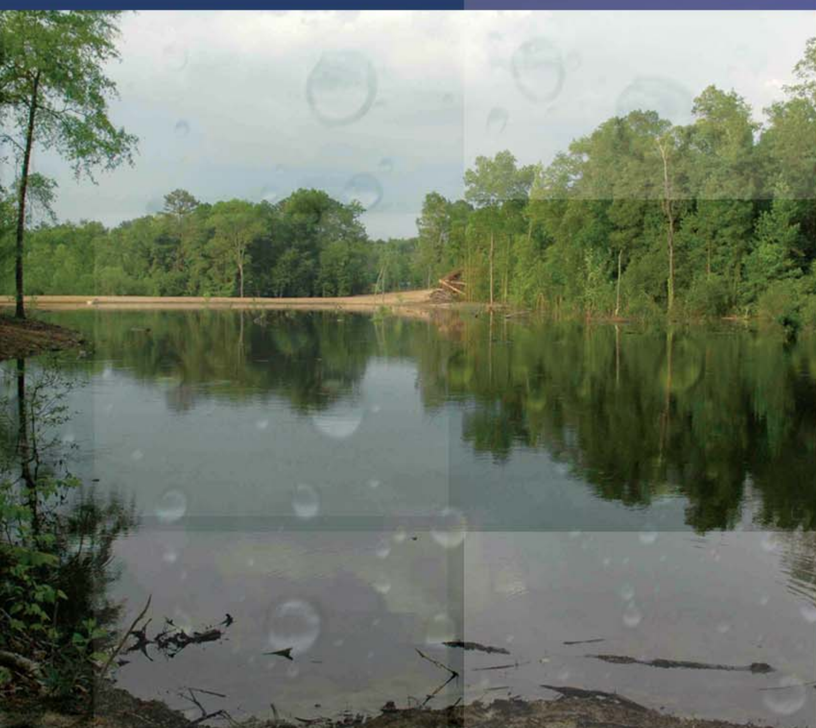
Water Quality BMP Manual

February 2008



For use in the following northeast Tennessee jurisdictions:

The City of Bristol, TN

The City of Elizabethton, TN

The City of Johnson City, TN

Table of Contents

CHAPTER 1 — The Need for Water Quality Management

Chapter 1 - List of Figures

Chapter 1 - List of Tables

This page left intentionally blank

CHAPTER

1

THE NEED FOR WATER QUALITY MANAGEMENT

1.1 Impacts of Development and Stormwater Runoff

Land development changes not only the physical, but also the chemical and biological conditions of Tennessee's streams. This chapter describes the changes that occur due to development and the resulting stormwater runoff impacts.

1.1.1 Development Changes Land and Runoff

When land is developed, the hydrology, or the natural cycle of water is disrupted and altered. Clearing removes the vegetation that intercepts, slows and returns rainfall to the air through evaporation and transpiration. Grading flattens hilly terrain and fills in natural depressions that slow and provide temporary storage of stormwater runoff. The topsoil and sponge-like layers of decaying leaves and other organic materials are scraped and removed and the remaining subsoil is compacted. Rainfall that once soaked into the ground now runs off the surface. The addition of buildings, roadways, parking lots and other surfaces that are impervious to rainfall further reduces infiltration and increases runoff.

Depending on the magnitude of changes to the land surface, the total runoff volume can increase dramatically. These changes not only increase the total volume of runoff, but also accelerate the rate at which runoff flows across the land. This effect is further exacerbated by drainage systems such as gutters, storm sewers and lined channels that are designed to quickly carry runoff to rivers and streams.

Development and impervious surfaces also reduce the amount of water that infiltrates into the soil and groundwater, thus reducing the amount of water that can recharge aquifers and feed streamflow during periods of dry weather.

Finally, development and urbanization affect not only the quantity of stormwater runoff, but also its quality. Development increases both the concentration and types of pollutants carried by runoff. As it runs over rooftops and lawns, parking lots and industrial sites, stormwater picks up and transports a variety of contaminants and pollutants to downstream waterbodies. The loss of the original topsoil and vegetation removes a valuable filtering mechanism for stormwater runoff.

The cumulative impact of development and urban activities, and the resultant changes to both stormwater quantity and quality in the entire land area that drains to a stream, river, lake or estuary determines the conditions of the waterbody. This land area that drains to the waterbody is known as its *watershed*. Urban development within a watershed has a number of direct impacts on downstream waters and waterways. These impacts include:

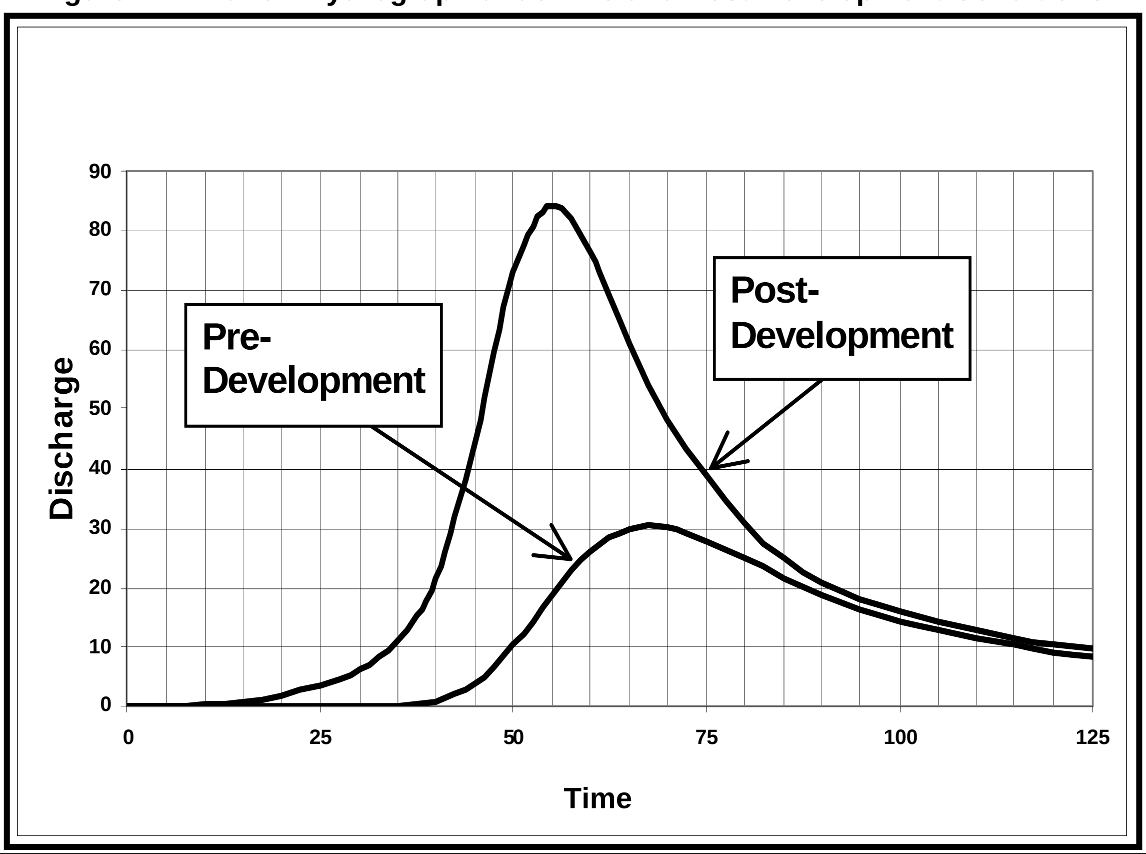
- Changes to stream flow;
- Changes to stream geometry;
- Degradation of aquatic habitat; and,
- Water quality impacts.

1.1.2 Changes to Stream Flow

Urban development alters the hydrology of watersheds and streams by disrupting the natural water cycle. This results in:

- Increased Runoff Volumes – Land surface changes can dramatically increase the total volume of runoff generated in a developed watershed.
- Increased Peak Runoff Discharges – Increased peak discharges for a developed watershed can be two to five times higher than those for a watershed prior to development. This is depicted in Figure 1-1.
- Greater Runoff Velocities – Impervious surfaces and compacted soils, as well as improvements to the drainage system such as storm drains, pipes and ditches, increase the speed at which rainfall runs off land surfaces within a watershed.
- Timing – As runoff velocities increase, it takes less time for water to run off the land and reach a stream or other waterbody.
- Increased Frequency of Bankfull and Near Bankfull Events – Increased runoff volumes and peak flows increase the frequency and duration of smaller bankfull and near bankfull events which are the primary channel forming events.
- Increased Flooding – Increased runoff volumes and peaks also increase the frequency, duration and severity of out-of-bank flooding.
- Lower Dry Weather Flows (Baseflow) – Reduced infiltration of stormwater runoff causes streams to have less baseflow during dry weather periods and reduces the amount of rainfall recharging groundwater aquifers.

Figure 1-1. Runoff Hydrograph under Pre-and Post-Development Conditions



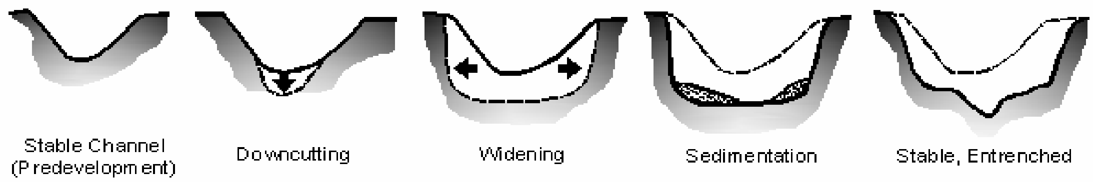
1.1.3 Changes to Stream Geometry

The changes in the rates and amounts of runoff from developed watersheds directly affect the morphology, or physical shape and character, of Tennessee's creeks and streams. This is depicted graphically in Figure 1-3. Some of the impacts due to urban development include:

- Stream Widening and Bank Erosion – Stream channels widen to accommodate and convey the increased runoff and higher stream flows from developed areas. More frequent small and moderate runoff events undercut and scour the lower parts of the streambank, causing the steeper banks to slump and collapse during larger storms. Higher flow velocities further increase streambank erosion rates. A stream can widen many times its original size due to post-development runoff. The photo in Figure 1-2 shows a good example of bank erosion.
- Stream Downcutting – Another way that streams accommodate higher flows is by downcutting their streambed. This causes instability in the stream profile, or elevation along a stream's flow path, which increases velocity and triggers further channel erosion both upstream and downstream.
- Loss of Riparian Tree Canopy – As streambanks are gradually undercut and slump into the channel, the trees that had protected the banks are exposed at the roots. This leaves them more likely to be uprooted during major storms, further weakening the bank structure.
- Changes in the Channel Bed Due to Sedimentation – Due to channel erosion and other sources upstream, sediments are deposited in the stream as sandbars and other features, covering the channel bed, or substrate, with shifting deposits of mud, silt and sand.
- Increase in the Floodplain Elevation – To accommodate the higher peak flow rate, a stream's floodplain elevation typically increases following development in a watershed due to higher peak flows. This problem is compounded by building and filling in floodplain areas, which cause flood heights to rise even further. Property and structures that had not previously been subject to flooding may now be at risk.

Figure 1-2. Example of Significant Streambank Erosion

Figure 1-3. Physical Stream Changes Due to Watershed Development



1.1.4 Impacts to Aquatic Habitat

Along with changes in stream hydrology and morphology, the habitat value of streams diminishes due to development in a watershed. Impacts on habitat include:

- Degradation of Habitat Structure – Higher and faster flows due to development can scour channels and wash away entire biological communities. Streambank erosion and the loss of riparian vegetation reduce habitat for many fish species and other aquatic life, while sediment deposits can smother bottom-dwelling organisms and aquatic habitat.
- Loss of Pool-Riffle Structure – Streams draining undeveloped watersheds often contain pools of deeper, more slowly flowing water that alternate with "riffles" or shoals of shallower, faster flowing water. These pools and riffles provide valuable habitat for fish and aquatic insects. As a result of the increased flows and sediment loads from urban watersheds, the pools and riffles disappear and are replaced with more uniform, and often shallower, streambeds that provide less varied aquatic habitat.
- Decline of Abundance and Biodiversity – When there is a reduction in various habitats and habitat quality, both the number and the variety, or diversity, of organisms (wetland plants, fish, macroinvertebrates, etc.) are also reduced. Sensitive fish species and other life forms disappear and are replaced by those organisms that are better adapted to the poorer conditions. The diversity and composition of the benthic, or streambed, community have frequently been used to evaluate the quality of urban streams. Aquatic insects are a useful environmental indicator as they form the base of the stream food chain.

Fish and other aquatic organisms are impacted not only by the habitat changes brought on by increased stormwater runoff quantity, but are often also adversely affected by water quality changes due to development and resultant land use activities in a watershed.

1.1.5 Water Quality Impacts

Nonpoint source pollution, which is the primary cause of polluted stormwater runoff and water quality impairment, comes from many diffuse or scattered sources, many of which are the result of human activities within a watershed. Development concentrates and increases the amount of these nonpoint source pollutants. As stormwater runoff moves across the land surface, it picks up and carries away both natural and human-made pollutants, depositing them into streams, rivers, lakes, wetlands, and groundwater. Nonpoint source pollution is the leading source of water quality degradation in northeast Tennessee. According to the State of Tennessee's list of impaired waters, sediment and habitat alteration are considered two major pollutants for streams in northeast Tennessee.

Water quality degradation in urbanizing watersheds starts when development begins. Erosion from construction sites and other disturbed areas contribute large amounts of sediment to streams. As construction and development proceed, impervious surfaces replace the natural land cover and pollutants from human activities begin to accumulate on these surfaces. During storm events, these pollutants are then washed off into the streams. Stormwater also causes discharges from sewer overflows and leaching from septic tanks. There are a number of other causes of nonpoint source pollution in urban areas that are not specifically related to wet weather events including leaking sewer pipes, sanitary sewage spills, and illicit discharge of commercial/industrial wastewater and wash waters to storm drains.

Due to the magnitude of the problem it is important to understand the nature and sources of urban stormwater pollution. Table 1-1 summarizes the major stormwater pollutants and their effects. Some of the most frequently occurring pollution impacts to urban streams and their sources are:

- Reduced Oxygen in Streams – The decomposition process of organic matter uses up dissolved oxygen (DO) in the water, which is essential to fish and other aquatic life. As organic matter is washed off by stormwater, dissolved oxygen levels in receiving waters can be rapidly depleted. If the DO deficit is severe enough, fish kills may occur and stream life can weaken and die. In addition, oxygen depletion can affect the release of toxic chemicals and nutrients from sediments deposited in a waterway.

All forms of organic matter in urban stormwater runoff such as leaves, grass clippings and pet waste contribute to the problem. In addition, there are a number of non-stormwater discharges of organic matter to surface waters such as sanitary sewer leakage and septic tank leaching.

- Microbial Contamination – The level of bacteria, viruses and other microbes found in urban stormwater runoff often exceeds public health standards for water contact recreation such as swimming and wading. Microbes can also contaminate shellfish beds, preventing their harvesting and consumption, as well as increasing the cost of treating drinking water. The main sources of these contaminants are sewer overflows, septic tanks, pet waste, and urban wildlife such as pigeons, waterfowl, squirrels, and raccoons.

Table 1-1. Major Stormwater Pollutants and Their Potential Effects

Constituents	Effects
Sediments - Suspended Solids, Dissolved Solids, Turbidity	Stream turbidity Habitat changes Recreation/aesthetic loss Contaminant transport Filling of lakes and reservoirs
Nutrients - Nitrate, Nitrite, Ammonia, Organic Nitrogen, Phosphate, Total Phosphorus	Algae blooms Eutrophication Ammonia and nitrate toxicity Recreation/aesthetic loss
Microbes - Fecal Coliforms, Fecal Streptococci, Viruses, E.Coli, Enterocci	Ear/intestinal infections Shellfish toxicity Recreation/aesthetic loss
Organic Matter - Vegetation, Sewage, Other Oxygen Demanding Materials	Dissolved oxygen depletion Odors Fish kills
Toxic Pollutants - Heavy Metals (cadmium, copper, lead, zinc), Organics, Hydrocarbons, Pesticides/Herbicides	Human & aquatic toxicity Bioaccumulation in the food chain
Thermal Pollution	Dissolved oxygen depletion Habitat changes
Trash and debris	Recreation/aesthetic loss

- Nutrient Enrichment – Runoff from urban watersheds contains increased nutrients such as nitrogen or phosphorus compounds. Increased nutrient levels are a problem as they promote weed and algae growth in lakes, streams and estuaries. Algae blooms block sunlight from reaching underwater grasses and deplete oxygen in bottom waters. In addition, nitrification of ammonia by microorganisms can consume dissolved oxygen, while nitrates can contaminate groundwater supplies. Sources of nutrients in the urban environment include washoff of fertilizers and vegetative litter, animal wastes, sewer overflows and leaks, septic tank seepage, detergents, and the dry and wet fallout of materials in the atmosphere.

- Hydrocarbons – Oils, greases and gasoline contain a wide array of hydrocarbon compounds, some of which have shown to be carcinogenic, tumorigenic and mutagenic in certain species of fish. In addition, in large quantities, oil can impact drinking water supplies and affect recreational use of waters. Oils and other hydrocarbons are washed off roads and parking lots, primarily due to leakage from vehicle engines. Other sources include the improper disposal of motor oil in storm drains and streams, spills at fueling stations and restaurant grease traps.

- Toxic Materials – Besides oils and greases, urban stormwater runoff can contain a wide variety of other toxicants and compounds including heavy metals such as lead, zinc, copper, and cadmium, and organic pollutants such as pesticides, PCBs, and phenols. These contaminants are of concern because they are toxic to aquatic organisms and can bioaccumulate in the food chain. In addition, they also impair drinking water sources and human health. Many of these toxicants accumulate in the sediments of streams and lakes. Sources of these contaminants include industrial and commercial sites, urban surfaces such as rooftops and painted areas, vehicles and other machinery, improperly disposed household chemicals, landfills, hazardous waste sites and atmospheric deposition.

- Sedimentation – Eroded soils are a common component of urban stormwater and a pollutant in their own right. Excessive sediment can be detrimental to aquatic life by interfering with photosynthesis, respiration, growth and reproduction. Sediment particles transport other pollutants that are attached to their surfaces including nutrients, trace metals and hydrocarbons. High turbidity due to sediment increases the cost of treating drinking water and reduces the value of surface waters for industrial and recreational use. Sediment also fills ditches and small streams and clogs storm sewers and pipes, causing flooding and property damage. Sedimentation can reduce the capacity of reservoirs and lakes, block navigation channels, fill harbors and silt estuaries. Erosion from construction sites, exposed soils, street runoff, and streambank erosion are the primary sources of sediment in urban runoff.

- Higher Water Temperatures – As runoff flows over impervious surfaces such as asphalt and concrete, it increases in temperature before reaching a stream or basin. Water temperatures are also increased due to shallow basins and impoundments along a watercourse as well as fewer trees along streams to shade the water. Since warm water can hold less dissolved oxygen than cold water, this “thermal pollution” further reduces oxygen levels in urban streams. Temperature changes can severely disrupt certain aquatic species, such as trout and stoneflies, which can survive only within a narrow temperature range.

- Trash and Debris – Considerable quantities of trash and other debris are washed through storm drain systems and into streams and lakes. The primary impact is the creation of an aesthetic “eyesore” in waterways and a reduction in recreational value. In smaller streams, debris can cause blockage of the channel, which can result in localized flooding and erosion.

1.1.6 Stormwater Hotspots

Stormwater hotspots are areas of the urban landscape that often produce higher concentrations of certain pollutants, such as hydrocarbons or heavy metals, than are normally found in urban runoff. These areas merit special management and the use of specific pollution prevention activities and/or structural stormwater controls. The local jurisdiction has the authority to require additional measures for developments and redevelopments that propose such hotspot land uses. Examples of stormwater hotspots include, but are not limited to:

- Gas/fueling stations
- Vehicle maintenance areas
- Vehicle washing / steam cleaning
- Auto recycling facilities
- Outdoor material storage areas
- Plant nurseries, agricultural areas
- Kennels, feed lots, etc.
- Loading and transfer areas
- Landfills
- Construction sites
- Industrial sites
- Industrial rooftops

1.1.7 Effects on Basins, Lakes and Reservoirs

Stormwater runoff into basins, lakes and reservoirs can have some unique negative effects. A notable impact of urban runoff is the filling in of lakes with sediment. Another significant water quality impact on lakes related to stormwater runoff is nutrient enrichment. This can result in the undesirable growth of algae and aquatic plants. Enclosed or regulated waterbodies such as basins, lakes and reservoirs do not flush contaminants as quickly as streams and act as sinks for nutrients, metals and sediments. This means that lakes can take longer to recover if contaminated.

1.2 Addressing Stormwater Impacts

The focus of this manual is effective and comprehensive water quality management. Water quality management involves both the prevention and mitigation of stormwater runoff quantity and quality impacts as described in this chapter through a variety of methods and mechanisms.

This manual provides requirements, policies, and guidance for developers to effectively implement water quality management controls on-site to address the potential impacts of new development and redevelopment, and both prevent and mitigate problems associated with stormwater runoff. This is accomplished by:

- Developing land in a way that minimizes its impact on a watershed by reducing both the amount of runoff and the pollutants generated;
- Using the most current and effective erosion and sedimentation control practices during the *construction* phase of development;
- Controlling stormwater to prevent downstream streambank channel erosion;
- Treating *post-construction* stormwater runoff before it is discharged to a waterway, and
- Implementing pollution prevention practices to prevent stormwater from becoming contaminated in the first place.

The remainder of Chapter 1 outlines the minimum water quality management standards that are used to guide the requirements, policies and incentives in establishing an effective water quality management program.

1.3 Comprehensive Water Quality Management Planning

This section presents a comprehensive and integrated set of water quality management standards for new development and redevelopment projects. Minimum standards and performance requirements for controlling runoff from development are critical to addressing the water quality impacts of post-construction urban stormwater and are required of the local jurisdictions in order to comply with the National Pollutant Discharge Elimination System (NPDES) stormwater regulations. Minimum water quality management standards must also be supported by a set of design and management tools and an integrated design approach for implementing both structural and nonstructural water quality facilities. The major elements of the water quality management program are:

- Incentives for Stormwater Better Site Design – The first step in addressing water quality management begins with the site planning and design process. The goals of better site development design are to reduce the amount of runoff and pollutants that are generated from a development site and provide for some nonstructural on-site treatment and control of runoff by implementing a combination of approaches collectively known as *stormwater better site design practices*. These include maximizing the protection of natural features and resources on a site, developing a site design that minimizes impact, reducing the overall site imperviousness, and utilizing natural systems for water quality management. General guidance on the types and application of better site design practices is provided in Chapter 5 of this manual.

- Water Quality Reductions for Better Site Design – This manual establishes a set of water quality "reductions" that can be used to provide developers and site designers' incentives to implement better site design practices that can reduce the volume of stormwater runoff and minimize the pollutant loads from a site. While reducing stormwater impacts, the reduction system can also translate directly into cost savings to the developer by reducing the size of structural water quality management and conveyance facilities. Specific technical guidance on the water quality reductions offered is presented in Chapter 5 of this manual.

- Stormwater Water Quality Treatment - Stormwater that does run off due to development and redevelopment shall be treated to remove pollutants prior to discharge from the development or redevelopment site. Stormwater management systems shall be designed to remove 80% of the post-development total suspended solids (TSS) load, based on the 85^{th} percentile storm event, and be able to meet any other additional watershed or site-specific water quality requirements, as determined the local jurisdiction. Design criteria and equations are presented in Chapter 3. It is presumed that a stormwater management system complies with this performance standard if:

  appropriate structural stormwater controls are selected, designed, constructed, and maintained according to the specific criteria in this manual; and

  runoff from hotspot land uses and activities is adequately treated and addressed through the use of appropriate structural stormwater controls and pollution prevention practices.

- Stream Channel Protection – Local streams are susceptible to erosion and degradation due to increased flows and flow durations. Protection of stream channels shall be provided through the capture and extended detention of the runoff volume from the 1-year return frequency, 24-hour duration storm event. Channel protection requirements are presented in Chapter 3 of this manual.

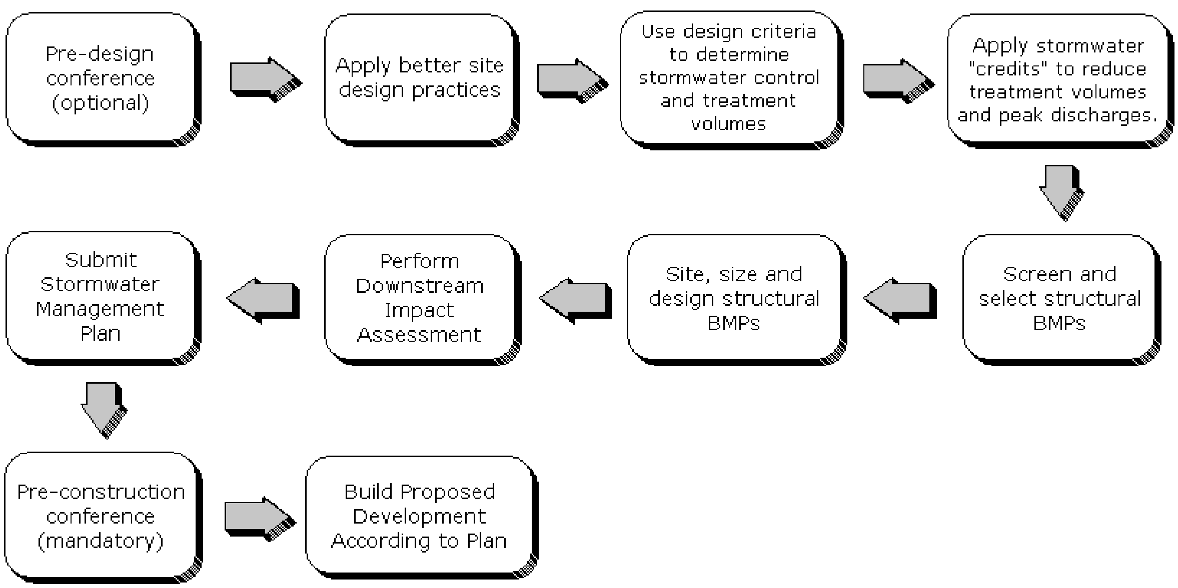
- Downstream Impact Analysis (e.g. the 10% rule) – Site peak discharge analyses are currently required by local jurisdictions for flood control. These regulations are not changed by this manual. However, the hydrologic analysis is extended downstream, to ensure that a proposed development is not adversely impacting downstream properties. These analyses can potentially be used to modify the requirement for overbank and extreme flood control, should the analysis reveal that such water quality management facilities would cause a negative flood impact on downstream properties. Downstream impact analysis requirements are presented in the Chapter 2 of this manual.

- Guidance on Structural Water Quality Management Facilities – This manual provides requirements and specifications for a set of structural water quality management facilities that can be used to meet the water quality management goals. Specific technical guidance on how to select, size, design, construct and maintain structural controls is provided in Chapter 4 of this manual.

- Water Quality Management Plan – Each local jurisdiction requires the preparation of a Water Quality Management Plan for development and redevelopment activities. The plan must be approved by the local jurisdiction prior to obtaining a grading or building permit. The purpose, requirements, and contents for this plan are discussed in Chapter 2 of this manual.

Figure 1-4 illustrates how these design tools can be utilized in the development process to address water quality management.

Figure 1-4. Water Quality Management Planning Process



1.4 Water Quality Treatment Rationale

This section provides an explanation of the requirement for 80% removal of total suspended solids (TSS) from post-construction stormwater runoff for the 85th percentile storm event, as measured on an average annual basis.

1.4.1 Regulatory Overview

The NPDES Phase II regulation requires that Phase II regulated communities develop, implement, and enforce a water quality management program that reduces the discharge of pollutants from the regulated jurisdiction "to the maximum extent practicable (MEP)". MEP is a technology-based discharge standard that was designed for the reduction of pollutant discharges and established in the Clean Water Act. Using guidance provided by the Environmental Protection Agency (EPA), the local jurisdiction can achieve the MEP standard by instituting a water quality management program that implements and requires best management practices (BMPs) that are designed to protect water quality. No further guidance on MEP is provided by the EPA or by the Tennessee Department of Environment and Conservation (TDEC).

Control measure 5 of the National Pollutant Discharge Elimination System (NPDES) Phase II Permit presents the requirements for the control of post-construction (i.e., after development) stormwater runoff. Quoting directly from the NPDES Permit for the State of Tennessee, regulated cities and counties must:

> *"Develop, implement, and enforce a program to address storm water runoff from new development and redevelopment projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale, that discharge into your small MS4. Your program must ensure that controls are in place that would prevent or minimize water quality impacts;*
>
> *Develop and implement strategies which include a combination of structural and/or non-structural best management practices appropriate for your community; and*
>
> *Develop and implement a set of requirements to establish, protect and maintain water quality buffers in areas of new development and redevelopment.*
>
> *Use an ordinance or other regulatory mechanism to address post-construction runoff from new development and redevelopment projects to the extent allowable under State or local law."*

As a result of these requirements, the local jurisdiction must implement a requirement for new developments and redevelopments to control water quality using both structural (i.e., constructed) and non-structural (i.e., site planning) best management practices (BMPs). This requirement must be fully implemented no later than 2008.

The NPDES Phase II regulation also requires that each jurisdiction focus water quality management on controlling discharges of pollutants of concern to local impaired streams. Based on the State of Tennessee's 303(d) list of "impaired" streams, one of the largest pollutants in northeast Tennessee is sedimentation. In 2006, over 300 stream miles were considered impaired due to excessive sedimentation.

1.4.2 Attaining the Water Quality Standard

The basic goal of the NPDES Phase II regulation is to reduce the water quality impacts of development. The preferred approach to meet this goal and comply with the NPDES permit is called the "Water Quality Volume method" or "WQv method". The WQv method is based on a minimum water quality control goal of 80% removal of TSS, as measured on an average annual basis, from post-construction stormwater runoff (i.e., after construction of a site is completed). TSS is a commonly used representative stormwater pollutant for measuring sedimentation.

There are a number of factors that support the use of an 80% TSS removal standard as a minimum level water quality goal in northeast Tennessee.

1. The Tennessee 303(d) list indicates that sedimentation (i.e., sediment) is a significant pollutant of concern in local streams. This fact alone requires implementation of a water quality management program that focuses on the removal of sediment from stormwater discharges in order to achieve compliance with the NPDES Phase II regulations to the maximum extent practicable.
2. The use of TSS as an "indicator" pollutant for sediment is well-established.
3. The control of TSS leads to indirect control of other pollutants of concern that can adhere to suspended solids in stormwater runoff. In fact, some research shows that a large fraction of many other pollutants of concern are either reduced along with TSS, or at rates proportional to the TSS reduction.
4. A treatment standard of 80% is not a numeric standard, but a "best available technology" standard. In other words, the 80% TSS removal level is reasonably attainable using properly

designed, constructed and maintained structural water quality BMPs (for typical ranges of TSS concentration found in stormwater runoff). This standard is supported with research data from numerous research projects and compiled in GeoSyntec et al (2000).

The WQv method can meet the goal of 80% TSS removal using a two-pronged approach. First, it encourages the reduction of imperviousness (and therefore pollution) from developed sites through incentives for non-structural BMPs, such as natural conservation areas and vegetated buffers. Second, it requires treatment of any remaining stormwater runoff with structural controls. This method allows the local jurisdiction to meet their water quality goals and regulatory requirements, yet still allows developers flexibility in their site designs.

There are a number of advantages with the WQv method:

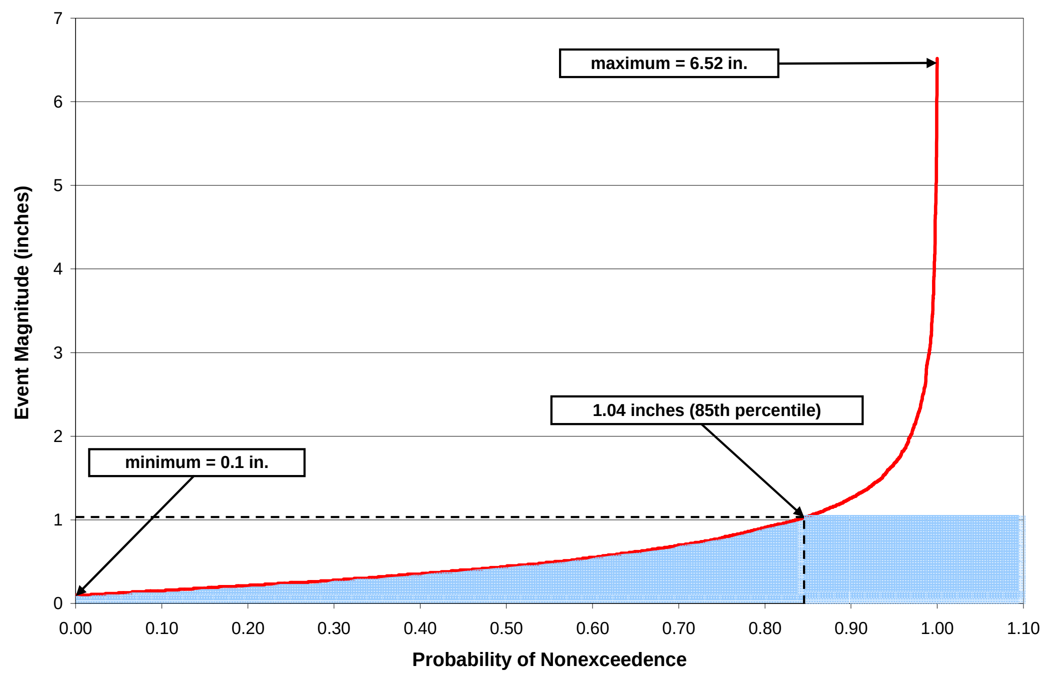
- If desired, the developer can utilize non-structural controls to reduce imperviousness. The WQv method will provide incentives for the reduction of impervious surfaces and the use of non-structural BMPs, such as buffers, natural space preservation, and impervious area disconnection. When utilized, these practices will reduce the amount of stormwater runoff that will require treatment by structural practices, thereby reducing the structural BMP maintenance burden;
- WQv is not a prescriptive approach in that it mandates the use of one specific treatment BMP, such as a first flush pond. Instead, the developer can choose from a menu of BMPs, each of which is assigned a % TSS removal efficiency. When constructed alone, or in combination with other structural and/or non-structural BMPs, the minimum percent TSS removal standard can be attained;
- Research shows that extended release “first flush” ponds, which are often called dry extended detention (ED) basins and are commonly used in East Tennessee, cannot attain a TSS removal standard of 80%. Such ponds have a high propensity for sediment resuspension and subsequent discharges, especially during large storm events. Recent studies of the BMP give it an average TSS reduction somewhere between 50% and 70% (Schueler and Holland, 2000). Of course, pollutant removal ability does depend upon geographic location, overall sediment characteristics, hydrology, and storm event size;
- WQv is a performance based approach. If the BMP(s) are designed, constructed and maintained in accordance with guidance and requirements set by this manual, then the BMP(s) will be considered “in compliance” with the minimum 80% water quality standard; and
- The WQv method allows a consistent, “apples-to-apples” application of water quality treatment practices on every development site. Each site will be required to design, construct and maintain in accordance with the 80% TSS removal goal.

The WQv is calculated for the 85th percentile storm event using a value of 1.04 inches of rainfall. Thus, a water quality management system designed for the WQv will treat the runoff from all storm events of 1.04 inches or less, as well as the first 1.04 inches of runoff for all larger storm events. The 85th percentile was chosen because it represents the “knee in the curve” volume that captures a significant number of storms (normally in the 80-90% range of all storms) without attempting to treat the small percentage of much larger storms that result in large volumes of runoff. Such storms would be expensive to treat, are rare in occurrence, and typically diluted in pollution concentration. Figure 1-5 presents a graphical representation of how the 85th percentile rainfall depth was determined, using a “knee-in-the-curve” approach. The value of 1.04 inches for the 85th percentile storm was approximated for the northeast Tennessee area based on analysis of rainfall data collected at the TriCities Airport dating back to 1948.

Detailed information on the calculation of the WQv and % TSS removal for a development or redevelopment site are presented in Chapter 3 of this manual.

It is important to note that this manual is not the first to implement the 80% TSS removal standard, or the WQv method. Many states, including Maryland, Massachusetts, North Carolina, Georgia, and Florida have set similar statewide TSS goals and have research data to support BMPs meeting this reduction goal. Further, a number of communities in Tennessee, the State of Georgia and the Commonwealth of Virginia have implemented a WQv type of method as the statewide water quality control approach. The BMP design and maintenance guidance from these states can be used and modeled as appropriate to implement a water quality control program that is appropriate to meet the needs of the local jurisdiction.

Figure 1-5: Northeast Tennessee 85th Percentile Rainfall Analysis



1.5 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

GeoSyntec Consultants, URS, et al. *Determining Urban Stormwater Best Management Practices Removal Efficiencies*. June, 2000.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Chapter 2 – Criteria for Stormwater Design.* 2007.

Schueler T., and Holland, H. *The Practice of Watershed Protection*. Center for Watershed Protection (CWP), 2000.

1.6 Suggested Reading

North Carolina Department of Environment and Natural Resources, *Stormwater Management Site Planning*. 1998

This page left intentionally blank

Table of Contents

CHAPTER 2 — Regulatory and Planning Guidance

Chapter 2 - List of Tables

This page left intentionally blank

CHAPTER

2

REGULATORY AND PLANNING GUIDANCE

2.1 Introduction

The purpose of this Chapter is to provide general information on the site planning process and relevant regulations and plans. This Chapter contains general information regarding the roles and requirements of the local jurisdiction and other agencies that have a role in the development process. The reader is referred to the local jurisdiction or agency of interest for detailed information on development process and procedures.

2.2 Applicable Regulations

2.2.1 Local Regulations

The policies, criteria and guidance provided in this manual are applicable only to water quality management. This manual does not provide information regarding land use planning, zoning, subdivision development, grading, erosion prevention and sediment control, stormwater drainage and detention (i.e., peak discharge) and infrastructure/building construction. Applicants submitting a Water Quality Management Plan (WQMP) must also refer to, and comply with, the local jurisdiction's relevant ordinances, permits and regulatory mechanisms for regulations and policies that are not included in this manual. Such regulations may include, but are not limited to, zoning ordinances, minimum subdivision regulations, erosion prevention and sediment control ordinances, grading and building permits, and ordinances that regulate drainage and water quantity.

This manual is not intended to repeal, abrogate, or impair any existing ordinances and regulations. However, where the policies in this manual and another regulation conflict or overlap, that provision which is more restrictive or imposes higher standards or requirements shall prevail.

2.2.2 Tennessee Construction General Permit

The State of Tennessee General NPDES Permit for Discharges of Stormwater Associated with Construction Activities is henceforth referred to as the "Construction General Permit" (TNCGP). Applicable to all areas of the State of Tennessee, the TNCGP is intended to regulate the pollution prevention and the control of wastes <u>during</u> construction activities, whereas the WQMP is intended to regulate the control of pollution <u>after</u> construction is completed. Specific to site developments, the TNCGP emphasizes the application of best management practices for purposes of erosion prevention and sediment control and the control of other construction related materials and wastes. The TNCGP is administered by the Tennessee Department of Environment and Conservation (TDEC).

2.2.3 Aquatic Resource Alteration Permit

Persons who conduct any activity that involves construction within, and potentially the alteration of, waters of the State must obtain a State Aquatic Resource Alteration Permit (ARAP), and possibly a Federal Section 401 Certification. ARAPs and 401 Certifications are administered by TDEC. The Section 401 Certification is required for projects involving the discharge of dredged or fill material into waters of the United States (US), or wetlands. An ARAP is required for any alteration of State waters, including wetlands that do not require a federal permit.

2.2.4 Section 404 (Wetlands) Permit

Section 404 of the Clean Water Act establishes a program to regulate the discharge of dredged and fill material into waters of the United States, including wetlands. Activities in waters of the United States that are regulated under this program include fills for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports), and conversion of wetlands to uplands for farming and forestry. The US Army Corps of Engineers administers the 404 permit program. The program governs such activities on all surface waters, such as inland waters, lakes, rivers, streams and their tributaries; interstate waters and their tributaries; wetlands adjacent to the above (e.g., swamps, marshes, bogs, or other land areas); and isolated wetlands and lakes, intermittent streams, and other waters where degradation could affect interstate commerce. Section 404 permits (and possibly Section 10 permits) are required for stormwater activities that may impact natural wetlands.

2.2.5 26a Permits for Shoreline Construction

The Tennessee Valley Authority (TVA) administers a permit program that governs shoreline construction along, across, or in the Tennessee River or any of its tributaries. Thus, TVA's jurisdiction for the 26a permit extends to the limits of the Tennessee River watershed. In accordance with TVA requirements, the permit applied to construction in the 500-year floodplain or to the upper limits of TVA flowage rights, whichever is higher, for developments located along regulated rivers (tailwaters) and TVA reservoirs (e.g., Fort Loudoun Lake). Along off-reservoir, unregulated streams and rivers, jurisdiction is typically applied to the limits of the 100-year floodplain. More information on the TVA 26a permit can be found at http://www.tva.gov.

2.2.6 Section 9 and 10 Permits for Navigable Waters

Sections 9 and 10 of the Rivers and Harbors Act of 1899 address the construction of bridges and other potential modifications or alterations of navigable waters of the United States. A Section 9 permit is required for construction of a bridge or other structure spanning navigable waters of the United States, without fill or dredging. The United States Coast Guard, as a part of the Department of Homeland Security, administers Section 9 permits. Section 10 permits are issued for fill, dredging, and other alterations of navigable waters. Section 10 permits are administered by the United States Army Corps of Engineers.

2.2.7 Endangered Species Act

The Federal Endangered Species Act (ESA) of 1973 protects plants and animals that are listed by the government as "endangered" or "threatened". The ESA makes it unlawful for any landowner to harm an endangered animal, or to significantly modify an endangered animal's habitat. This applies to both public and private lands. Water Quality Management Plan requirements that relate to endangered species are contained later in this chapter. More information on the Endangered Species Act can be gathered from the Tennessee Wildlife Resources Agency (http://www.state.tn.us/twra), or the United States Fish and Wildlife Service (www.fws.gov).

2.2.8 State/Federal Water Quality Regulations

There are two major, State-administered, regulatory programs that provide the basis for local jurisdictional water quality regulations: the General Permit for Discharges from Small Municipal Separate Storm Sewer Systems (MS4s), henceforth called the MS4 Permit; and the Total Maximum Daily Load (TMDL). Both regulations are administered by TDEC. Local jurisdictions are responsible for the community's compliance with the MS4 Permit and TMDL, and therefore have imposed water quality management regulations on new developments and redevelopments. Both State-administered regulations are discussed briefly below.

2.2.8.1 NPDES MS4 (Phase II) Permit

The MS4 Permit falls under the National Pollutant Discharge Elimination System (NPDES) program, and establishes guidelines for municipalities to minimize pollutants in stormwater runoff to the "maximum extent practicable." The MS4 permit is directly applicable to the local jurisdiction, which has the responsibility for maintaining local government compliance with the permit requirements. As a result, each local jurisdiction that must comply with the MS4 Permit has in turn imposed a similar set of regulations on developments and redevelopments, pertaining to non-stormwater (i.e., illicit) discharges and dumping, erosion prevention and sediment control (EPSC), and, most relevant to this manual, water quality management. While a site developer or property owner has no direct responsibility with regards to compliance with the MS4 permit, it is important to understand that the conditions of the MS4 Permit do affect local water quality management requirements during and after construction.

2.2.8.2 Total Maximum Daily Load Program

Under Section 303(d) of the Clean Water Act, the State of Tennessee is required to develop a list of impaired waters that do not meet water quality standards (i.e., the 303(d) list). TDEC must then establish priority rankings for waters on the list and develop TMDLs for listed waters. The TMDL specifies the maximum amount of a specific pollutant of concern that a designated segment of a water body can receive and still meet water quality standards. The TMDL also allocates pollutant loadings among point and non-point pollutant sources, including stormwater runoff. TMDLs have been issued for water bodies in northeast Tennessee, and more are anticipated.

The TMDL program has the potential for broad impact on the local water quality management program and property development regulations because it requires that non-point sources of pollutants must be addressed at the local level. The program requires the development of a plan that may impose requirements or restrictions for specific local regulations or programs, and therefore it is important for persons that are planning new developments or redevelopments to be aware of TMDLs and where they are applicable. Adopted TMDL plans are available from TDEC or at TDEC's website (http://www.state.tn.us/environment). As well, local jurisdictions can provide information on any local water quality management requirements that may result from a State-imposed TMDL.

2.3 Pre-Design Conference

This Water Quality BMP Manual contains many different BMPs and "better site design" alternatives that can be applied on a new development or redevelopment site. As a result of this, there is a large degree of flexibility in the design of a site that is offered to local developers and site design engineers. Prior to submittal of site design plans, local jurisdictions that adopt this manual encourages the use of a pre-design conference with the developer and site designer to discuss potential site layout, design, and construction sequence.

A pre-design conference is not mandatory. The developer is encouraged to invite representatives of other regulatory or permitting agencies to the pre-design conference. The objectives of this meeting would be to:

- Review the site topography, existing vegetative condition, and preliminary site development lay-out (if already determined);
- identify the natural drainage conditions (for new development) and existing drainage conditions (for redevelopments);
- identify any environmentally-sensitive features, such as streams, wetlands, sinkholes, and steep slopes, that should be avoided by the development or redevelopment;
- discuss preliminary strategies for site clearing, grading and construction;

- discuss preliminary design strategies for erosion and sediment control, road geometry and layout, water quality treatment practices, vegetated buffers, and encourage the use of better site design practices and water quality volume (WQv) reductions; and,
- determine how the technical guidelines and criteria presented in this manual should be applied to the site.

The local jurisdiction is not responsible for development of a design plan for the site as a result of the pre-design conference. Further, the pre-design conference should not be considered as an endorsement or pre-approval of any design plans that will be submitted to the local jurisdiction later in the development process. The developer is responsible for requesting and scheduling the pre-design conference, and for inviting others as appropriate for his/her needs (e.g., the site design engineer, representatives of other permitting agencies).

2.4 Water Quality Management Plans (WQMPs)

The WQMP is defined as the engineering plan for the design of water quality management facilities and best management practices within a proposed development or redevelopment. This section includes specific requirements and information on plan contents and approval requirements, and provides general guidance on the approval process.

2.4.1 General Policies

The reader is referred to the local jurisdiction's water quality management regulation for provisions pertaining to WQMPs. Beyond those provisions, the policies that shall apply to WQMPs are listed below.

- The WQMP must be submitted as part of, and at the same time as, the larger subdivision or site plan for the development or redevelopment, along with any required plan review fees. The WQMP will be reviewed for compliance with local water quality management regulations, this manual, and any other applicable local requirements. Only complete plans will be accepted for review.
- Issuance of a grading and/or building permit may be contingent on approval of the WQMP. The reader is referred to other applicable regulations or policies for information on the local jurisdiction's subdivision or site plan submittal/review/approval process.
- If applicable to the proposed new development or redevelopment, an Endangered Species Act (ESA) Review shall be completed prior to submittal of a WQMP. The results of the ESA Review must be submitted as part of the Plan. The WQMP cannot be reviewed or approved if the ESA Review has not been performed. ESA Review applicability is addressed in section 2.4.2 of this chapter.
- A checklist that provides a complete inventory of the required contents of a WQMP is presented in Appendix C of this manual. Use of this checklist is required, to ensure submittal of a complete plan and expedite the plan review process. The Plan shall include, at a minimum, the elements listed in the checklist, unless the element is not applicable to the project. These requirements should be checked as "not applicable." Omission of any required items renders the plans incomplete, and they will be returned to the applicant, or their engineer, so that they may be completed. When the WQMP is submitted, the applicant must attach a signed copy of the checklist to certify that a complete package is being submitted.
- If applicable to the proposed new development or redevelopment, a Special Pollution Abatement Plan (SPAP) shall be required for submittal as part of the WQMP. SPAP applicability is addressed in section 2.4.3 of this chapter.
- The applicant may also be required to meet State and Federal regulations for construction activities that will have an impact on Waters of the State, wetlands, sinkholes and threatened

or endangered species. It is the responsibility of the applicant to thoroughly review, understand and adhere to all applicable local, state and federal laws and regulations with regard to site development and property regulations when submitting the WQMP. Copies of all applicable State and Federal permits must be provided to the local plan review agency as part of the WQMP.

- An executed maintenance covenants document must be included in the WQMP for grading and/or building permits to be granted.

2.4.2 Endangered Species Act Review

The MS4 Permit (discussed previously in this chapter) requires the local jurisdiction to consider the potential impacts of stormwater discharges on species that are listed as endangered or threatened under the ESA and on habitat that is designated as "critical" under the ESA. **Because of these requirements, any proposed development that is located within, or discharges stormwater runoff to, an area designated as containing threatened species, endangered species, or critical habitat (as defined by the ESA) shall be reviewed by the United States Fish and Wildlife Service (USFWS) prior to submittal of a WQMP**. If USFWS determines that the proposed development may, or will, impact an endangered or threatened species, or critical habitat, an informal consultation may be required by USFWS to determine the BMPs that will mitigate the potential ESA-related impacts. Often, such impacts will be construction related, and therefore will impact the design of erosion prevention and sediment control measures. **It is the responsibility of the property owner to work with USFWS to ensure compliance with the ESA.**

Local governments are not the regulatory agencies tasked with enforcing the ESA, and therefore cannot advise the property owner on ESA compliance practices and options. However, BMPs that are utilized to mitigate ESA-related impacts must be:

- approved by USFWS (or other agency as designated by USFWS); and,
- included in the WQMP, or other plan as appropriate, and must be identified on such plan(s) as "USFWS-accepted BMPs";

Once plan approval is received by the local jurisdiction, USFWS-accepted BMPs that are shown on plans will be enforced by the local jurisdiction as a matter of compliance with approved plans. Variations from USFWS-accepted BMPs shown on approved plans will not be allowed by the local jurisdiction without a copy of written acceptance of such variations by USFWS.

Local governments do not have the authority to expedite USFWS reviews and informal consultations. Therefore, person(s) responsible for proposed developments should consider the additional time required to coordinate with USFWS when preparing development schedules and costs. Questions regarding a USFWS consultation for any particular site should be forwarded to the USFWS office in Cookeville, Tennessee. Contact information for USFWS is presented in Appendix B.

In order to facilitate an understanding of when ESA Reviews are needed, each local jurisdiction has a Threatened and Endangered Species Buffer Map. This map shall be used to determine which proposed developments will require review by USFWS. This map is prepared and maintained by the USFWS, and is available from the local jurisdiction for use by the general public. The map will be updated by the local jurisdiction as needed to remain current.

Proposed developments that are located within an area identified on the Threatened and Endangered Species Buffer Map, or are located in a watershed that discharges to a buffered stream shown on the map, must submit for a review by USFWS. A copy of the results of the USFWS determination must be provided, in writing, with all WQMP plans submitted to the local jurisdiction. Further, proposed developments that undergo informal consultation by USFWS must also present, in detail, the BMPs that have been accepted by USFWS to mitigate ESA-related impacts. A copy of the BMP acceptance by USFWS must also be provided. WQMPs that do not comply with these requirements will not be accepted for review.

2.4.3 Special Pollution Abatement Plans

A Special Pollution Abatement Plan (SPAP) may be required for new developments and redevelopments on the basis of: 1) land use or type of business; 2) a history of air or water pollution at a site; 3) a history of air or water pollution by an owner/operator at other sites; 4) the potential to impact environmentally sensitive areas, such as wetlands; or 5) at the discretion of the local jurisdiction upon sound engineering judgment. The local jurisdiction's water quality regulation(s) will provide information on the applicability of a SPAP. A SPAP template is provided in Appendix C of this manual.

To obtain coverage under a SPAP, the property or business owner must submit a SPAP (see Appendix C) and any application fee, if appropriate, with the WQMP. The SPAP requires supporting documentation for the BMP(s) proposed to reduce or mitigate special pollutants, including BMP specifications and maintenance information. SPAP-related BMPs must be included in the Record Drawings for the site.

Like any water quality BMP, SPAP related BMPs must be maintained in proper operating condition throughout the life of the land use or business, or otherwise as appropriate for the conditions of the site. It is the responsibility of the property owner to inspect and maintain SPAP-related BMPs, and to document such inspections and maintenance activities. Such documentation must be maintained by the property owner and provided to the local jurisdiction upon request. Further, the local jurisdiction shall have the authority to inspect SPAP-related BMPs for long-term operation and performance, and to order corrective actions if necessary.

The following minimum standards shall be addressed in the SPAP:

- **Employees and/or staff of the business or land use type shall be trained annually on the requirements of the SPAP,** specifically addressing pollution source controls such as spill control and cleanup, proper waste management, chemical storage, and fluids management with vehicle servicing. The type of training shall be tailored to and appropriate for the land use or business. Documentation of the training shall be maintained with the SPAP and made available to the local jurisdiction upon request.
- **Parking lots shall be swept monthly to remove gross solids.** Waste gathered during sweeping activities shall be disposed of properly.
- **Animal waste shall be prevented from entering streams, sinkholes, wetlands, ponds or any other component of the storm drain system.** Controls shall be instituted to collect the animal waste and properly treat or dispose of it.
- **Structural BMPs that have been designed to specifically address the target pollutants associated with the land use shall be utilized where appropriate to reduce pollutant loadings.** This requirement does not alleviate new developments and redevelopments from water quality treatment design criteria for total suspended solids (TSS), as discussed in Chapter 3. BMPs that are implemented to comply with SPAP minimum standards can factor into the % TSS calculation, provided that they have TSS removal capabilities. Percent TSS removal values and policies for water quality BMPs are presented in Chapter 3 of this manual. Table 2-1 presents target pollutants for the land uses for which a SPAP is required.
- **Structural BMPs shall be inspected and maintained by the owner/permittee.** Inspections must be conducted at least annually. Maintenance shall be conducted as needed and as required by the manufacturer of the structural BMP or by the local jurisdiction. Documentation

of such inspections shall be maintained by the owner and made available to the local jurisdiction upon request.

Table 2-1. Target Pollutants for SPAP Land Uses

Land use	Target Pollutant
Vehicle, truck or equipment maintenance, fueling, washing or storage areas including but not limited to: automotive dealerships, automotive repair shops, and car wash facilities	Oil, grease, detergents, solids, metals
Recycling and/or salvage yard facilities	Oil, grease, metals
Restaurants, grocery stores, and other food service facilities	Oil, grease, trash
Commercial facilities with outside animal housing areas including animal shelters, fish hatcheries, kennels, livestock stables, veterinary clinics, or zoos	Bacteria, nutrients
Other producers of pollutants identified by the local jurisdiction by information provided to or collected by him/her or his/her representatives, or reasonably deduced or estimated by him/her or his/her representatives from engineering or scientific study	As identified by the local jurisdiction

Chapter 7 of this manual provides additional information pertaining pollution prevention after construction is complete. As well, it should be noted that the *City of Knoxville Best Management Practices (BMP) Manual* provided the basis for the SPAP discussed in this manual, and provides excellent reference material for BMPs that can be utilized for pollution prevention for many different types of land uses or activities.

2.5 Bonds

A performance bond may be required by the local jurisdiction for land disturbing activities, and/or the construction of new developments and redevelopments when:

1) there is a potential for runoff to adversely impact local rights-of-way, other property, and/or streams, wetlands, ponds or lakes; or,
2) an erosion prevention and sediment control plan is required; or,
3) a WQMP is required; or,
4) the area of grading or development drains to one or more sinkholes; or,
5) the site is used for a borrow pit.

The purpose of the performance bond is to ensure that the person(s) responsible for completing the land disturbing activities and/or construction work that has the potential to impact the public interest if performed improperly completes the work in an appropriate manner. The performance bond provides assurance to the local jurisdiction that it will be reimbursed when it must assume the costs of corrective measures and/or work not completed by the responsible person(s) according to the required specifications and approved plans. A performance bond can be used to cover the local jurisdiction's costs for water quality management facilities and related appurtenances, the installation and maintenance of EPSC measures and EPSC corrective actions, final soil stabilization of a site, and the establishment, protection, and maintenance of vegetated buffers.

Performance bonds are administered by the local jurisdiction. The dollar amount of the performance bond will be determined, based on the information presented in the approved EPSC Plan and/or WQMP. Check with your local jurisdiction for more information on bonds.

General policies regarding release of a performance bond are as follows.

1) An accurate Record Drawing showing all water quality management facilities must be completed.

2) Portions of the property that will be used for the stormwater management system must be recorded as a permanent drainage, water quality, preservation, and/or access easement, as appropriate for each system component.

3) If found within the boundaries of the development, any one of the following items could keep areas or activities from being released from the performance bond:

    - areas of erosion or unstabilized areas;
    - potential for discharges of sediment, or construction-related and other wastes;
    - engineering or structural deficiencies or maintenance issues associated with constructed roadways, the stormwater system, or water quality best management practices;
    - unsafe conditions;
    - unhealthy, damaged or poorly growing vegetation in a vegetated buffer that has been impacted by construction.

2.6 Covenants & Private Ownership

Local post-construction water quality management ordinances requires property owners to enter, into permanent maintenance agreements for water quality best management practices before the property is developed, as a condition of approval of the WQMP. This is accomplished by completing and submitting the "Covenants for Permanent Maintenance of Water Quality Facilities and Best Management Practices" (also called the "Maintenance Covenants"). A blank copy of the Maintenance Covenants is presented in Appendix E of this manual.

2.7 Record Drawings

Policies pertaining to record drawing are as follows.

- Prior to obtaining a Certificate of Occupancy, two (2) complete copies of record drawings with the appropriate professional certifications must be approved by the local jurisdiction. The drawings will be compared to the approved site or subdivision plan for any irregularities or non-conformance with the approved plans. An electronic copy shall also be provided in a format acceptable to the city.

- The record drawings shall reflect the as-constructed condition of the development, and shall include sufficient information to demonstrate substantial conformance with the approved plan(s). Significant deviations from the approved plan(s) shall be considered violations of local ordinances and are grounds for the invocation of the injunctions and penalties defined therein, and/or withholding the release of a bond pending the completion of corrective action(s), and/or requiring a submittal of a revised WQMP. In the event that submittal of a revised plan is required, the revision shall include a description of the discrepancies between the site conditions and the prior approved WQMP, along with design calculations that demonstrate that the as-constructed conditions comply with local water quality management facility requirements.

- Should the as-constructed conditions be shown to have a negative impact regarding flooding, maintenance, erosion or water quality, other mitigation measures and proposed design plans to mitigate any potential impacts from the development may be required.

- Only complete record drawings will be accepted. The record drawing checklist presented in Appendix E shall be included to indicate that a complete plan is being submitted. Record drawings shall contain the information and certification(s) listed, as applicable to the development. Some requirements of the checklist in Appendix E will not be applicable to all projects. These requirements should be checked as “not applicable”. Additional information may be requested as necessary to allow a thorough review of the as-constructed conditions. Omission of any required items shall render the record drawings incomplete, and they will be returned to the applicant, or their engineer, so that they may be completed.

- Plats, easements and BMP locations shown must be field checked by the property owner or developer prior to submitting the record drawing to ensure that the field locations are approximately correct. Prior to submittal of the record drawings, all easements and survey plats must be recorded with the Register of Deeds, and any protective covenants pertaining to water quality management facilities shall be executed. Copies of the recorded documents or other verification of the recording shall be included with the record drawings.

- Record drawings must be prepared and stamped by the design professional that stamped the original WQMP, and/or a registered land surveyor licensed to practice in the State of Tennessee. Land surveyors providing record drawings must provide the following certification, in addition to the surveyor’s seal and an original signature and date across the seal.

I hereby certify that I have surveyed the land boundaries and easements shown hereon in accordance with the accuracy requirements for a Category I survey and that the ratio for precision of the unadjusted survey is not less than 1:10,000.

I further certify that I have located all natural and manmade features shown hereon in accordance with the current Standards of Practice as adopted by the Tennessee State Board of Examiners for Land Surveyors. I certify the location, elevation and description of these features.

______________________	______________	____________
Printed name	*Date*	*RLS Number*

The reviewing engineer shall provide the following certification, in addition to the engineer’s seal and an original signature and date across the seal.

Based upon site observations and/or information provided by a registered land surveyor, I hereby certify that all grading, drainage, structures and/or systems, erosion and sediment control practices including facilities and vegetative measures, have been completed in substantial conformance with the approved plans and specifications.

______________________	______________	____________
Printed name	*Date*	*PE Number*

2.8 References

City of Knoxville. *BMP Manual.* City of Knoxville Engineering Department, Stormwater Division.

City of Knoxville. *Land Development Manual.* City of Knoxville Engineering Department, Stormwater Division, June 2006.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 1 – Administration and Procedures.* 2007.

Table of Contents

CHAPTER 3 — Water Quality Standards

Chapter 3 - List of Figures

Chapter 3 - List of Tables

Chapter 3 - List of Equations

Chapter 3 - List of Examples

This page left intentionally blank

CHAPTER
3

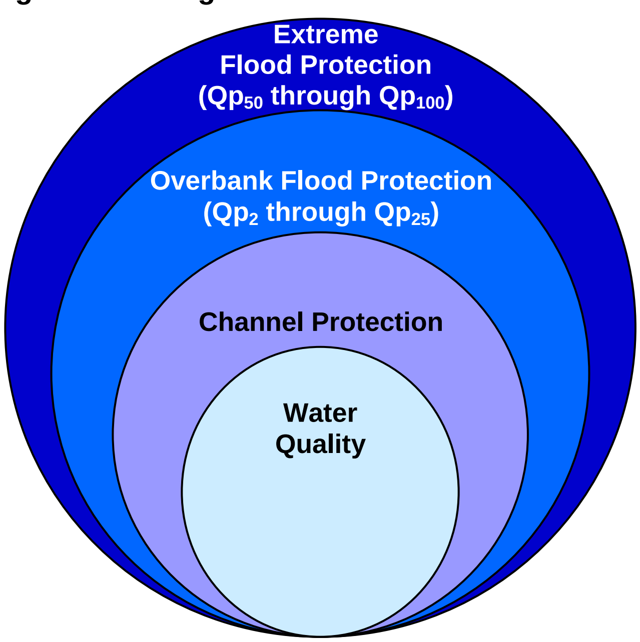
WATER QUALITY STANDARDS

3.1 Water Quality Protection Approach

This chapter represents policies, criteria and calculation methods for the design of the water quality best management practices (BMPs) presented in Chapter 4 of this manual. The design criteria presented herein communicate the regional approach to address the key adverse impacts of stormwater runoff from a development site presented in Chapter 1. The purpose of the design criteria is to provide a framework for design of the site's stormwater management system in order to remove stormwater runoff pollutants, improve water quality, and prevent downstream streambank and channel erosion. This chapter does not provide criteria and calculation guidance for stormwater quantity (e.g., hydraulic drainage design, detention/retention) design; please refer to the ordinances and other regulatory code of the local jurisdiction for stormwater quantity regulations.

While this manual does not address local stormwater quantity design requirements, site designers should note that design criteria for water quality, channel protection and stormwater quantity can often be blended together. This enables the sizing and design of structural stormwater controls in conjunction with each other to address the overall stormwater impacts from a development site. When stormwater design criteria are considered as a set, the site designer can control the range of design events, from the smallest amounts of runoff that are treated for water quality, to events requiring extreme flood protection, such as the 100-year storm. Figure 3-1 graphically illustrates the relative volume requirements of the various stormwater controls and demonstrates that, in some cases, the controls can be "nested" within one another (i.e., the extreme flood protection volume requirement also contains the overbank flood protection volume, the channel protection volume and the water quality treatment volume).

Figure 3-1. Integration of Stormwater Controls



3.2 General Policies

The following general policies shall apply to all water quality management and channel protection design calculations.

1. Design computations shall be performed in accordance with the calculation guidance provided in this manual, or other criteria that the local jurisdiction establishes based on scientific and engineering information.
2. Stormwater runoff resulting from post-development conditions must be routed at appropriately small time intervals through water quality BMPs, as appropriate, using either hand calculations or computer models that are widely accepted among engineering professionals.
3. All design computations utilized in the design of water quality BMPs must be prepared by a registered engineer or landscape architect proficient in the field of hydrology and hydraulics and licensed to practice in the State of Tennessee.

3.3 Water Quality Management

3.3.1 Minimum Standard and General Policies

Local ordinances require that stormwater runoff discharging from new development or redevelopment sites be treated to remove pollutants prior to discharge from the site. This requirement shall be implemented in accordance with the **Water Quality Minimum Treatment Standard** and associated policies presented in items 1 through 5 below. Policies that are specific to individual design calculations and/or BMPs are included later in this chapter.

1. Water quality BMPs shall be designed to remove, at a minimum, 80% of the average annual post-development total suspended solids (TSS) load from the stormwater volume required for water quality treatment, called the water quality treatment volume (WQv). This standard is also referred to in this manual as “the 80% TSS removal standard”.
2. WQv and % TSS removal shall be calculated for the development or redevelopment in accordance with the policies and calculation guidance provided in this chapter. In order to comply with the 80% TSS removal standard, the result of the % TSS removal calculations for the development or redevelopment must be equal to, or greater than, 80%.
3. It is presumed that a stormwater management system complies with the Water Quality Minimum Treatment Standard if structural BMPs are selected, designed, constructed and maintained in accordance with the design criteria specified in this manual. Only those BMPs that are published in Chapter 4 of this manual are permitted for use as a water quality BMPs. Other BMPs are prohibited, unless approved by the local jurisdiction. The structural BMPs deemed acceptable for use to attain the Water Quality Minimum Treatment Standard are listed in Table 3-1.
4. Table 3-1 also presents the % TSS removal value assigned to each BMP. This value shall be used to calculate the total weighted % TSS removal for the development site.
5. The local jurisdiction may require additional water quality treatment criteria or controls to conform to State and/or Federal regulatory requirements, and/or additional watershed or site-specific water quality requirements that are defined by the State or Federal officials, or the local jurisdiction. For example, additional treatment criteria may be required if, in the opinion of the local jurisdiction, the new development or redevelopment is considered a pollutant “hotspot”, where the land use or activities may generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. Examples of hot spot land uses might include operations producing concrete or asphalt, auto repair shops, auto supply shops, large commercial parking areas, restaurants.

Table 3-1. TSS Removal % for Structural BMPs

Structural BMP	TSS Removal %
General Application BMPs	
Wet Basin	80
Wet Extended Detention	80
Micropool Extended Detention Basin	80
Multiple Basin System	80
Dry Extended Detention Basin	60
Conventional Dry Detention Basins	10
Shallow Wetland	80
Extended Detention Shallow Wetland	80
Basin/Wetland System	80
Pocket Wetland	80
Bioretention Area	85
Sand Filters (Surface and Perimeter)	80
Infiltration Trench	90
WQ Dry Swales	90
Wet Swales	75
Filter Strip	50
Grass Channel[1]	30
Gravity (oil-grit) Separator	30
Modular Porous Paver Systems[2]	*
Porous Pavement/Concrete[2]	*
Limited Application BMPs	
Organic Filter	80
Underground Sand Filter	80
Submerged Gravel Wetland	75
Alum Treatment System	90
Manufactured BMPs	10[3]
Underground Detention	10

1 – Refers to open channel practice not designed for water quality.
2 – These practices are not treatment BMPs but are source control BMPs, so they are not assigned a pollutant removal.
3 – Provisional % TSS Removal value pending third party information. See Section 4.4.5 in Chapter 4 for policies for manufactured BMPs.

3.3.2 Calculation of % TSS Removal

The % TSS removal for the BMPs proposed for a new development or redevelopment must be calculated using the equations presented in this section.

3.3.2.1 Multiple BMPs

Equation 3-1 is an area-weighted TSS reduction equation that accounts for the TSS reduction that is contributed from each water quality BMP that is utilized on the site. This equation is applicable to those developments or redevelopments where multiple BMPs are used to treat the WQv. If only one BMP is utilized for WQv treatment, then the % TSS removal value is simply that assigned to the BMP (see Table 3-1). Equation 3-1 is applicable in situations where a site has multiple subwatersheds that flow to different BMPs, and none of the BMPs are placed downstream of another BMP.

Equation 3-1

$$\%TSS = \frac{\sum_{1}^{n}(TSS_1 A_1 + TSS_2 A_2 + \ldots + TSS_n A_n)}{\sum_{1}^{n}(A_1 + A_2 + \ldots + A_n)}$$

where:

TSS_n = TSS removal percentage for each structural BMP located on-site (%);
A_n = the area draining to each BMP (acres).

3.3.2.2 BMPs in Series

It will often be the case that the site designer will want to use two or more BMPs (structural and/or non-structural) in series, where stormwater treated in one BMP is discharged into another BMP for further treatment. Such BMP combinations are also called treatment trains. How and why BMPs might be used in treatment trains is discussed in Chapter 4 of this manual. This section presents the calculation of the total % TSS removal for treatment trains.

Equation 3-2 is used to calculate the total % TSS removal for a treatment train comprised of two or more structural BMPs.

Equation 3-2

$$TSS_{train} = TSS_A + TSS_B - \frac{(TSS_A \times TSS_B)}{100}$$

where:

TSS_{train} = total TSS removal for treatment train (%);
TSS_A = % TSS removal of the first (upstream) BMP, from Table 3-2 (%)
TSS_B = % TSS removal of the second (downstream) BMP, from Table 3-2 (%).

For development sites where the treatment train provides the only water quality treatment on the site, TSS_{train} must be greater than or equal to 80%. For development sites that have other structural BMPs for water quality treatment that are not included in the treatment train, TSS_{train} must be included in Equation 3-1 in the calculation of the overall % TSS removal for the site. An example application of the latter situation is presented below.

Example 3-1. Calculation of %TSS for BMPs in Series

A water quality management system located on a 30 acre development site consists of a dry extended detention basin, a water quality dry swale, and a shallow wetland. The extended detention basin and dry swale are located in series, with the basin as the upstream control. The treatment train treats stormwater runoff from 20 acres of the site. The shallow wetland treats 10 acres. All three facilities are designed in accordance with this manual. What is the % TSS removal rate for the site?
The % TSS removal value for each BMP located on the site is determined from Table 3-1, as follows:

Control A (dry extended detention basin) = 60% TSS removal

Control B (water quality dry swale) = 90% TSS removal
Control C (shallow wetland) = 80% TSS removal

Step 1: Calculate TSS_{train}:

TSS_{train} = A + B – (A x B)/100 = 60 + 90 - (60 X 90)/100 = 96% removal

Step 2: Calculate % TSS removal for the site:

%TSS = ((TSS_{train} x 20 acres) + (%$TSS_{wetland}$ x 10 acres)) ÷ 30 acres
%TSS = ((96% x 20 acres) + (80% x 10 acres)) ÷ 30 acres = 91%

Therefore, the % TSS removal for the site is 91%, which exceeds the minimum standard of 80% TSS removal. No other BMPs need to be constructed at the site.

3.3.2.3 Calculation of % TSS Removal for Flow-through Situations

BMPs within a treatment train may sometimes be separated by a contributing drainage area. In this case, equation 3-2 cannot be used, since some of the flow entering the downstream BMP has not been treated by the upstream BMP. This section presents the calculation of the total % TSS removal for flow-through situations.

To calculate the total % TSS removal for a treatment train separated by a contributing drainage area, Equation 3-3 shall be used.

Equation 3-3

$$TSS_{train} = \frac{TSS_A A_A + TSS_B A_B + \frac{TSS_B A_A (100 - TSS_A)}{100}}{A_A + A_B}$$

where:

TSS_{train} = total TSS removal for treatment train (%);
TSS_A = % TSS removal of the first (upstream) BMP, from Table 3-2 (%)
TSS_B = % TSS removal of the second (downstream) BMP, from Table 3-2 (%)
A_A = Area draining to BMP A
A_B = Area draining to BMP B.

For development sites where the treatment train provides the only stormwater treatment on the site, TSS_{train} must be greater than or equal to 80%. An example application of Equation 3-3 is shown below.

Example 3-2. Calculation of %TSS in a Flow-through Situation

A stormwater management system located on a 9 acre development site consists of a dry extended detention pond, and a bioretention cell. Five acres drain to the bioretention cell, which then drains to a pipe system. The pipe system also drains an additional 4 acres that have not been treated for water quality. The pipe system leads to a dry extended detention pond, that is used for final treatment. Both facilities are designed in accordance with the guidance in this manual. What is the % TSS removal rate for the site?

The % TSS removal value for each BMP located on the site is determined from Table 2-2, as follows:

Control A (bioretention cell) = 85% TSS removal
Control B (dry extended detention pond) = 60% TSS removal

Step 1: Calculate TSS_{train}:

$$TSS_{train} = \frac{TSS_A A_A + TSS_B A_B + \dfrac{TSS_B A_A (100 - TSS_A)}{100}}{A_A + A_B}$$

$$TSS_{train} = \frac{85x5 + 60x4 + \dfrac{60*5(100-85)}{100}}{5+4}$$

$$TSS_{train} = 78.9\%$$

The % TSS removal for the site is 78.9%, which is below the minimum standard of 80% TSS removal. The conversion of the stormwater pipe system to a grass swale would add additional pollutant removal and help the site meet the 80% criteria.

3.3.3 Calculation of the Water Quality Volume (WQv)

The calculation of % TSS removal tells the designer how well the water is treated. Next, the designer must consider how *much* water must be treated. The volume of water that must be treated to the 80% TSS removal standard is called the water quality volume (WQv). Compliance with the 80% TSS removal standard requires the calculation of the WQv for the entire development site. To obtain the lowest WQv for the site, this calculation should be performed *after* better site design practices that may be envisioned for the site have been considered and are included in design plans.

The WQv shall be calculated using Equation 3-4, as follows:

Equation 3-4

$$WQv = \frac{PRvA}{12}$$

where:

WQv = water quality volume of the site (acre-feet);
P = rainfall depth for the 85% storm event (1.04 inches);
Rv = runoff coefficient; and,
A = site area (acres).

The runoff coefficient (Rv) shall be calculated using Equation 3-5.

Equation 3-5

$$Rv = 0.015 + 0.0092I$$

where:

I = percent impervious area of the site (see Equation 3-6 below).

3.3.4 The Determination of Percent Imperviousness

Impervious areas are defined as impermeable surfaces which prevent the percolation of water into the soil. Impervious surfaces include, but are not limited to, paved surfaces such as walkways, sidewalks, patios, parking areas and driveways, packed gravel or soil, and structure rooftops. Other examples of impervious areas are paved recreation areas including pool houses and pool decks intended for use as a private (multi-family) or public recreation area, paved athletic courts (e.g., basketball, tennis), and storage buildings.

The percent impervious area (I) that is used to determine WQv is calculated using Equation 3-6.

Equation 3-6

$$I = \frac{I_A}{A} X100\%$$

where:

I_A = cumulative area of all impervious surfaces on the site (acres);
A = site area (acres).

The determination of the impervious area (I_A) in order to calculate WQv shall be performed in the following manner:

1. For residential subdivisions that will be served by one or more water quality BMPs, I_A shall be determined using percent (%) impervious values that were developed by the Soil Conservation Service (SCS)[1]. Where the average lot size of a subdivision or a drainage area within the subdivision falls between the lot size categories shown in Table 3-2, the site designer may interpolate the % impervious value based on Table 3-2.

Table 3-2. % Impervious Area Values for Subdivisions

Residential Lot Size Range[1]	% Impervious
Less than ¼ acre	65
¼ acre	38
⅓ acre	30
½ acre	25
¾ acre	22.5[2]
1 acre	20
2 acres and greater	15

1 – Includes lots and streets. Common areas must be measured separately.
2 – The % impervious value is linearly interpolated from SCS data.

The values shown in Table 3-2 shall be utilized only for the portion of the subdivision that is covered by individual residential lots and streets. Other areas, such as common areas for recreation or meeting facilities, shall be added separately in the calculation of I_A. The calculation of the % impervious value for a residential subdivision having a common area is presented in Example 3-3.

If lot sizes within a single subdivision fall into more than one of the lot size ranges listed in Table 3-2, the site designer shall consider the total amount of imperviousness in each lot range separately in the determination of the percent impervious value. Example 3-3 includes the calculation of the % impervious value for a residential subdivision having variable lot sizes.

[1] The Soil Conservation Service is now known as the Natural Resource Conservation Service (NRCS).

2. For planned unit developments where the building and paving footprints are known, as well as all nonresidential developments, I_A shall be determined from the measured impervious footprints for all impervious areas as defined above. It is required that the footprint for all impervious surfaces in the proposed development and the calculation of I_A be shown in the stormwater management plan.

After the development and/or redevelopment of the property is complete, property improvement activities that do not require the submittal of a water quality management plan will not require recalculation of the impervious percentage and WQv.

Example 3-3. Calculation of Percent Impervious Area (I)

A site design engineer is preparing a water quality management plan for a proposed residential development. The subdivision has a total area of 31 acres, and will include 52 residential lots ranging in area from approximately ¼ acre to no greater than 1 acre (as shown in the table below). Three (3) acres will be preserved as an undisturbed forested vegetated buffer located along a stream that crosses the property, and therefore, there is no impervious coverage within these three acres. Another three (3) acres will be utilized for a recreational common area which includes a community pool, tennis courts and an associated parking lot. Due to local topography on the site, the subdivision drains to two separate water quality management facilities, herein called Facility A and Facility B, both of which provide water quality treatment. Twelve acres, including the 3 acre vegetated buffer and 3 acre common area, drain to Facility A. The other 19 acres drain to Facility B. The following table provides lot size, area and impervious data for the proposed subdivision. What is the % impervious area for the site?

A Lot Size	B Number of Lots in Size Range	C Sub-total Area of Lots in Size Range	D % Impervious (from Table 3-2)
DRAINAGE AREA A (AREA DRAINING TO FACILITY A)			
approx. ⅓ acre	0	0 acres	30
approx. ½ acre	0	0 acres	25
approx. ¾ acre	2	1.3 acres	22.5
approx. 1 acre	5	4.7 acres	20
Area A Totals	7 lots	6.0 acres	--
DRAINAGE AREA B (AREA DRAINING TO FACILITY B)			
approx. ⅓ acre	21	6.6 acres	30
approx. ½ acre	16	7.3 acres	25
approx. ¾ acre	7	4.3 acres	22.5
approx. 1 acre	1	0.8 acres	20
Area B Totals	45 lots	19.0 acres	--

Since the site will be served by two separate detention facilities, it is best to determine the impervious area for each drainage area, rather than the overall impervious area for the site. For ease in calculation, the site design engineer decided not to interpolate impervious area values, preferring to group lots into approximate lot sizes that correspond to Table 3-2.

Step 1: Determine the total impervious area for the portion of each drainage area that is covered by residential lots and associated subdivision roads ($I_{\text{residential areas}}$):

This is calculated by multiplying the sub-total area of each lot size range (column C from the above table) by the corresponding % impervious in that lot size range (column D from the above table). Results of this calculation are shown in the table below.

A Lot Size	B Sub-total Area of Lots in Size Range	C % Impervious (from Table 3-2)	D Sub-total Impervious Area
DRAINAGE AREA A (AREA DRAINING TO FACILITY A)			
approx. ⅓ acre	0 acres	30	0 x 0.30 = 0 ac
approx. ½ acre	0 acres	25	0 x 0.25 = 0 ac
approx. ¾ acre	1.3 acres	22.5	1.3 x 0.225 = 0.29 ac
approx. 1 acre	4.7 acres	20	4.7 x 0.20 = 0.94 ac
Area A Totals	6.0 acres	--	1.23 acres

DRAINAGE AREA B (AREA DRAINING TO FACILITY B)			
approx. ⅓ acre	6.6 acres	30	6.6 x 0.30 = 1.98 ac
approx. ½ acre	7.3 acres	25	7.5 x 0.25 = 1.88 ac
approx. ¾ acre	4.3 acres	22.5	4.3 x 0.225 = 0.97 ac
approx. 1 acre	0.8 acres	20	0.8 x 0.20 = 0.16 ac
Area B Totals	19.0 acres	--	4.99 acres

Thus, the portions of the site where residential lots are located are covered by impervious surfaces as follows:
$I_{A\ residential\ areas}$ = 1.23 acres
$I_{B\ residential\ areas}$ = 4.99 acres

Step 2: Measure the area of impervious footprints in the common areas that are located in Area A ($I_{A\ common\ areas}$):

The following table presents the measurements of the impervious areas located in the common area.

Area Description	Impervious Area
Community pool (includes pool, surrounding deck, maintenance building and sidewalk from parking lot)	0.8 acres
Tennis court (includes two courts, surrounding paved areas, and sidewalk from parking lot)	1.2 acres
Common area driveway and parking lot	0.7 acres
Total impervious areas	2.7 acres

Thus, 2.7 acres of the 3 acre common area, located in Area A, is covered by impervious surfaces. $I_{A\ common\ areas}$ = 2.7 acres

Step 3: Calculate the % impervious area (I) for each drainage area of the site using Equation 3-6. Because the vegetated buffer is entirely undisturbed, and therefore entirely pervious, it is not considered in the calculation.

For Area A:

$I_A = ((I_{A\ residential\ areas} + I_{A\ common\ areas}) \div 12\ acres)\ X\ 100\%$

$I_A = ((1.23\ acres + 2.7\ acres) \div 12\ acres)\ X\ 100\%$

$I_A = (3.9\ acres \div 12\ acres)\ X\ 100\%$

$I_A = 32.8\%$

For Area B:

$I_B = (I_{B\ residential\ areas} \div 19\ acres)\ X\ 100\%$

$I_B = (4.99\ acres \div 19\ acres)\ X\ 100\%$

$I_B = 26.3\%$

Therefore, the % impervious area for Area A (I_A) for the site is 32.8%. The % impervious area for Area B (I_B) is 26.3%.

3.3.5 Reducing the WQv

It is important to remember that the WQv is proportional to impervious area, such that the amount of stormwater runoff requiring treatment increases as impervious area increases. In other words, the more you pave, the more you treat. Therefore, to reduce the amount of stormwater runoff that must be treated, the developer must find ways to reduce site imperviousness. Reductions in imperviousness are beneficial from a water quality management standpoint. Decreases in impervious area equate to less runoff, lower post-development peak discharges, and typically lower pollutant discharges. This can result in lower water quality management costs, as structural BMPs, channel protection, and flooding protection controls can be smaller in size.

In order to reduce the WQv for a development site, site designers are encouraged to use better site design practices. Better site design can be defined as a combination of non-structural design approaches intended to reduce the impacts of stormwater runoff from development through the conservation of natural areas, reduction of impervious areas, and integration of non-structural water quality BMPs. Such practices are often collectively referred to as “non-structural practices or non-structural BMPs”. By implementing a combination of these non-structural approaches, it is possible to reduce the amount of runoff and pollutants that are generated from a site and provide for some non-structural on-site treatment and control of runoff.

The use of better site design practices on a development or redevelopment site to attain the 80% TSS removal standard is not required. A strong incentive for the use of such practices is provided via the WQv method (since it is proportional to impervious area) and through prescribed WQv reductions for the use of specific better site design practices. The WQv reductions are listed in Table 3-3 on the following page. Check with the local jurisdiction to determine which of these reductions are available for use in that jurisdiction. Detailed policies and design requirements for reductions and better site design practices are presented in Chapter 5 of this manual.

3.3.6 The Design of Outlets Used for Extended Detention

Once the WQv has been determined, the volume must be treated to the 80% TSS removal standard through the use of the BMPs found in Chapter 4. Several of the BMPs achieve TSS removal through extended detention (ED). Therefore, ED orifice sizing is required for these BMPs. For a structural control facility that will provide both WQv extended detention and channel protection volume control (to be discussed in section 3.4) (wet ED pond, micropool ED pond, and shallow ED wetland), there will be a need to design two outlet orifices. The water quality control outlet will be sized using drawdown time principles described below. The minimum standard for the channel protection and the sizing of the channel protection outlet is discussed in detail in section 3.4.

Table 3-3. Summary of WQv Reductions for Better Site Design

WQv Reduction	Description
Reduction 1: Natural area preservation	Undisturbed natural areas are conserved, thereby retaining the pre-development hydrologic and water quality characteristics.
Reduction 2: Managed area preservation	Managed areas of open space are preserved, reducing total site runoff and retaining near pre-development hydrologic and water quality characteristics.
Reduction 3: Stream and vegetated buffers	Stormwater runoff is treated by directing sheet flow runoff through a naturally vegetated or forested buffer as overland flow.
Reduction 4: Vegetated channels	Vegetated channels are used to provide water quality treatment.
Reduction 5: Impervious area disconnection	Overland flow filtration/infiltration zones are incorporated into the site design to receive runoff from rooftops and other small impervious areas.
Reduction 6: Environmentally sensitive large lot neighborhood	A group of site design techniques are applied to low and very low density residential development.

(The following procedures are based on the water quality outlet design procedures included in the Virginia Stormwater Management Handbook, 1999)

In an extended detention facility for water quality treatment, the storage volume is detained and released over a specified amount of time (e.g., no less than 24-hours). The release period is a brim drawdown time, with the assumption that the entire WQv is present in the basin at the beginning of drawdown. The entire calculated volume drains out of the basin over no less than 24 hours. In reality, however, water is flowing out of the basin prior to the full or brim volume being reached. Therefore, the extended detention outlet can be sized using either of the following two methods:

1. Use the maximum hydraulic head associated with the storage volume and maximum flow, and approximate the orifice size needed to achieve the required drawdown time. This procedure is outlined in Example 3-5.
2. Use a drawdown analysis to determine the drawdown time.

This is a accurate method for determining orifice sizes. Example 3-5 illustrates this method.

Example 3-4. ED Outlet Design Method 1: Maximum Hydraulic Head

A wet ED pond sized for the required water quality volume will be used here to illustrate the sizing procedure for an extended-detention orifice. Given the following information, calculate the required orifice size for water quality design.

- Water Quality Volume (WQv) = 0.76 ac-ft = 33,106 ft^3
- Maximum Hydraulic Head (H_{max}) = 5.0 ft (from stage vs. storage data)

Step 1. Determine the maximum discharge resulting from the 24-hour drawdown requirement. It is calculated by dividing the WQv by the required time to find the average discharge, and then multiplying by two to obtain the maximum discharge.

Q_{avg} = 33,106ft³/(24hr)(3,600sec/hr) = 0.38 cfs
Q_{max} = $2Q_{avg}$ = 0.76 cfs

Step 2. Determine the required orifice diameter by using the standard orifice equation and Q_{max} and H_{max}:
Q = $CA(2gH)^{0.5}$, or $A = Q/C(2gh)^{0.5}$
A = $0.76/0.6[(2)(32.2)(5.0)]^{0.5} = 0.071\ ft^2$

Step 3. Determine pipe diameter
A = $3.14d^2/4$, then $d = (4A/3.14)^{0.5}$
D = $[4(0.071)/3.14]^{0.5} = 0.30$ ft = 3.61 inches

Therefore, use a 3.6-inch diameter water quality orifice.

Example 3-5. ED Outlet Design Method 2: Drawdown Analysis

Using the data from the previous example (Example 3-4) use Method 2 to calculate the size of the outlet orifice. Use of a spreadsheet is highly recommended.

- Water Quality Volume (WQv) = 0.76 ac-ft = 33,106 ft^3
- Maximum Hydraulic Head (H_{max}) = 5.0 ft (from stage vs storage data)

Step 1. Determine the pond stage-storage curve at increments of 0.1' or less.

Step 2. Choose pond water elevation (first increment at H_{max}, others at end elevation of previous increment).

Step 3. Assume an orifice size:
Orifice diameter = 1"
Orifice area = $(\pi/4)*(Diam/12)^2$
Orifice area = $(3.14/4)*(1/12)^2 = 0.00545\ ft^2$

Step 4. Calculate flowrate at water surface elevation using orifice equation:
$Q = CA(2gH)^{0.5}$
$Q = 0.6*0.00545*(2*32.2*5)^{0.5}$
Q = 0.0587 cfs

Step 5. Calculate time to drain pond volume increment (keeping track of elapsed time):
Time = Volume/Flowrate (Volume of increment from stage-storage curve)
Time = 200/.0587 = 3407 seconds = 56.8 minutes

Step 6. Repeat steps 1 through 5 for each elevation from WQv elevation to orifice center (keeping track of elapsed time).

Step 7. Check whether total drawdown time is greater than 24-hours:

3.3.7 Calculating the Water Quality Peak Discharge

The peak rate of discharge for the water quality design storm (Q_{wq}), also called the water quality peak discharge, is needed to size water quality BMPs that are located off-line, such as sand filters and infiltration trenches. See Chapter 4 of this manual for more information on off-line (versus on-line) BMPs.

This method is utilized for the sizing of water quality treatment controls. More traditional peak discharge calculation methods are not appropriate for this application for a variety of reasons. First, the use of more traditional methods, such as the Rational Method would require the choosing of an arbitrary design storm event that will differ from the 85th percentile storm event that must be treated for water quality. Further, conventional SCS methods have been found to underestimate the volume and rate of runoff for rainfall events of less than two inches. This discrepancy in estimating runoff and discharge rates can lead to situations where a significant amount of runoff bypasses the structural control due to an inadequately sized diversion structure and leads to the design of undersized bypass channels.

The method employed to calculate the water quality peak discharge uses the runoff coefficient to find the depth of runoff for the water quality storm of 1.04 inches. The SCS method is then used to find a unit peak discharge that is combined with the runoff depth to find a peak runoff rate.

The following procedure can be used to calculate Q_{wq}. This procedure relies on the Rv and the simplified peak discharge calculation:

1. Utilize Equation 3-7 to calculate D_{wq}.

Equation 3-7

$$D_{wq} = 1.04Rv$$

where:
- D_{wq} = water quality runoff depth, in inches
- Rv = runoff coefficient (see Equation 3-5)

2. A runoff curve number (CN) can be estimated using the standard SCS Runoff Curve Number estimation technique, or can be computed utilizing Equation 3-8 (Pitt, 1994).

Equation 3-8

$$CN = \frac{1000}{10 + 5P + 10D_{wq} - 10\left(D_{wq}^{2} + 1.25D_{wq}P\right)^{1/2}}$$

where:
- CN = runoff curve number
- P = the 85th percentile rainfall, in inches (use 1.04 inches)
- D_{wq} = water quality runoff depth, in inches (see Equation 3-7)

3. Determine the initial abstraction (I_a) from Table 3-4, and the ratio I_a/P is then computed (P = 1.04 inches).

4. Compute the drainage area time of concentration (t_c) for the post-development land use with standard SCS methods.

5. The time of concentration is used with the ratio I_a/P to obtain the unit peak discharge, q_u, from Figure 3-2 for the Type II rainfall distribution. If the ratio I_a/P lies outside the range shown in the figure, use the limiting values.

6. The water quality peak discharge (Q_{wq}) is computed using Equation 3-9.

Equation 3-9

$$Q_{wq} = q_u A D_{wq}$$

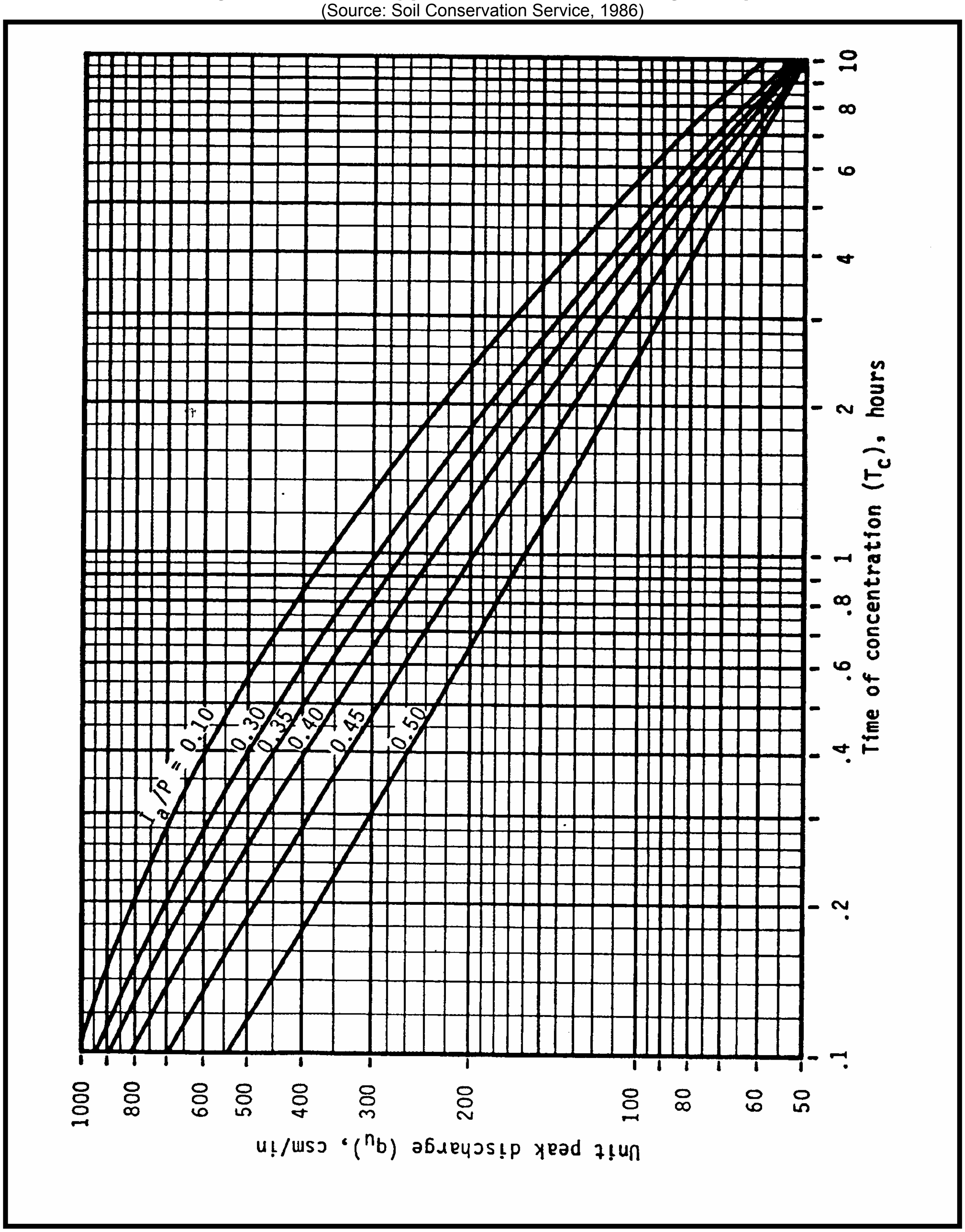
where:

Q_{wq} = the water quality peak discharge (cfs)
q_u = the unit peak discharge (cfs/mi²/inch)
A = drainage area (mi^2)
D_{wq} = water quality runoff depth, in inches (see Equation 3-7)

Table 3-4. Initial Abstraction (I_a) for Runoff Curve Numbers
(Source: SCS, TR-55, Second Edition, June 1986)

Curve Number	I_a (in)	Curve Number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899	-	

Figure 3-2. SCS Type II Unit Peak Discharge Graph
(Source: Soil Conservation Service, 1986)



An example illustrating calculation of the water quality peak flow is given below.

Example 3-6. Calculation of Water Quality Peak Flow
For a 50 acre site, with 18 impervious acres.

Step 1: Compute volumetric runoff coefficient, Rv using Equation 3-5:

Rv = 0.015+(0.0092)(I) = 0.015+(0.00920(18/50)(100) = 0.35

Step 2. Compute depth of runoff that must be treated for water quality, D_{wq} using equation 3-7:

D_{wq} = 1.04Rv = 1.04(0.35) = 0.36 inches

Step 3: Compute the synthetic curve number (CN) using Equation 3-8:

CN = 1000/[10 + 5(1.04) + 10(0.36) – 10[$(0.36)^2$ +1.25(0.36)(1.04)$]^{0.5}$= 90

Step 4: Find Ia from CN with Table 3-4:

Ia = 0.22 inches
Ia/P = 0.22/1.04 = 0.21

Step 5: Compute time of concentration, Tc: using SCS standard methods

Tc computed as 0.35 hours.

Step 6: Find q_u, using Tc = 0.35 and I_a/P = 0.21 using Figure 3-2:

q_u = 580 cfs/mi²/in

Step 7: Compute water quality peak flow rate using Equation 3-9.

Q_{wq} = 580(50/640)(0.36)(1) = 16.3 cfs

3.3.8 Water Balance Calculations

Water balance calculations can help to determine if a drainage area is large enough or has the right characteristics to support a permanent pool of water during average or extreme conditions. When in doubt, a water balance calculation may be advisable for retention pond and wetland design.

The details of a rigorous water balance are beyond the scope of this manual. However, a simplified procedure is described herein that will provide an estimate of pool viability and point to the need for more rigorous analysis. Water balance can also be used to help establish planting zones in a wetland design.

3.3.8.1 Basic Equations

Water balance is defined as the change in volume of the permanent pool resulting from the total inflow minus the total outflow (actual or potential). Equation 3-10 presents this calculation.

Equation 3-10 $$\Delta V = \sum I - \sum O$$

where:

- Δ = delta or "change in"
- V = basin volume (ac-ft)
- Σ = "the sum of"
- I = Inflows (ac-ft)
- O = Outflows (ac-ft)

The inflows consist of rainfall, runoff and baseflow into the basin. The outflows consist of infiltration, evaporation, evapotranspiration, and surface overflow out of the basin or wetland. Equation 3-10 can be expanded to reflect these factors, as shown in Equation 3-11. Key variables in Equation 3-11 are discussed in detail below the equation.

Equation 3-11 $$\Delta V = PA + R_o + Bf - ID - EA - EtA - Of$$

where:

- P = precipitation (ft)
- A = area of basin (ac)
- R_o = runoff (ac-ft)
- B_f = baseflow (ac-ft)
- I = infiltration (ac-ftt)
- E = evaporation (ft)
- Et = evapotranspiration (ft)
- Of = overflow (ac-ft)
- D = number of days in a given month

Rainfall (P) – Monthly rainfall values can be obtained from the National Weather Service climatology at *http://www.srh.noaa.gov/mrx/climat.htm.* Monthly values are commonly used for calculations of values over a season. Rainfall is then the direct amount that falls on the basin surface for the period in question. When multiplied by the basin surface area (in acres) it becomes acre-feet of volume. Table 3-5 presents average monthly rainfall values for northeast Tennessee based on a 30-year period of record.

Table 3-5. Average Rainfall Values in Feet for the Tri-Cities

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
P (feet)	0.29	0.28	0.33	0.27	0.36	0.32	0.35	0.25	0.26	0.19	0.26	0.28
Annual Precipitation 3.44												

Source: www.ncdc.noaa.gov/oa/climate/online/ccd/nrmpcp.txt

Runoff (R_o) – Runoff is equivalent to the rainfall for the period times the "efficiency" of the watershed, which is equal to the ratio of runoff to rainfall (Q/P). In lieu of gage information, Q/P can be estimated one of several ways. The best method would be to perform long-term simulation modeling using rainfall records and a watershed model.

Equation 3-12 gives a ratio of runoff to rainfall volume for a particular storm. If it can be assumed that the average storm that produces runoff has a similar ratio, then the Rv value can serve as the ratio of rainfall to runoff. Not all storms produce runoff in an urban setting. Typical initial losses (often called "initial abstractions") are normally taken between 0.1 and 0.2 inches. When compared to the rainfall records in northeast Tennessee, this is equivalent to about a 10% runoff volume loss. Thus, in a water balance calculation, a factor of 0.9 should be applied to the calculated Rv value to account for storms that produce no runoff. Equation 3-13 reflects this approach. Total runoff volume is then simply the product of runoff depth (Q) times the drainage area (A) to the basin, as shown in equation 3-12.

Equation 3-12 $$R_o = QxA$$

where:

R_o = total runoff volume
Q = runoff depth (ft)
A = basin area (ft^2)

Equation 3-13 $$Q = 0.9PRv$$

where:

Q = runoff depth (ft)
P = precipitation (ft)
Rv = volumetric runoff coefficient (Equation 3-5)

Baseflow (B_f) – Most water quality basins and wetlands have little, if any, baseflow, as they are rarely placed across perennial streams. If so placed, baseflow must be estimated from observation or through theoretical estimates. Methods of estimation and baseflow separation can be found in most hydrology textbooks.

Infiltration (I) – Infiltration is a very complex subject and cannot be covered in detail here. The amount of infiltration depends on soils, water table depth, rock layers, surface disturbance, the presence or absence of a liner in the basin, and other factors. The infiltration rate is governed by the Darcy equation, shown in Equation 3-14.

Equation 3-14 $$I = Ak_hG_h$$

where:

I = infiltration (ac-ft/day)
A = cross sectional area through which the water infiltrates (ac)
k_h = saturated hydraulic conductivity or infiltration rate (ft/day)
G_h = hydraulic gradient = pressure head/distance

G_h can be set equal to 1.0 for basin bottoms and 0.5 for basin sides steeper than about 4:1. Infiltration rate can be established through testing, though not always accurately. Table 3-6 can be used for initial estimation of the saturated hydraulic conductivity.

Table 3-6. Saturated Hydraulic Conductivity
(Source: Ferguson and Debo, 1990)

Material	Hydraulic Conductivity Kh	
	in/hr	ft/day
ASTM Crushed Stone No. 3	50,000	100,000
ASTM Crushed Stone No. 4	40,000	80,000
ASTM Crushed Stone No. 5	25,000	50,000
ASTM Crushed Stone No. 6	15,000	30,000
Sand	8.27	16.54
Loamy sand	2.41	4.82
Sandy loam	1.02	2.04
Loam	0.52	1.04
Silt loam	0.27	0.54
Sandy clay loam	0.17	0.34
Clay loam	0.09	0.18
Silty clay loam	0.06	0.12
Sandy clay	0.05	0.10
Silty clay	0.04	0.08
Clay	0.02	0.04

Evaporation (E) – Evaporation is from an open lake water surface. Evaporation rates are dependent on differences in vapor pressure, which, in turn, depend on temperature, wind, atmospheric pressure, water purity, and shape and depth of the basin. It is estimated or measured in a number of ways, which can be found in most hydrology textbooks. Pan evaporation methods are also used.

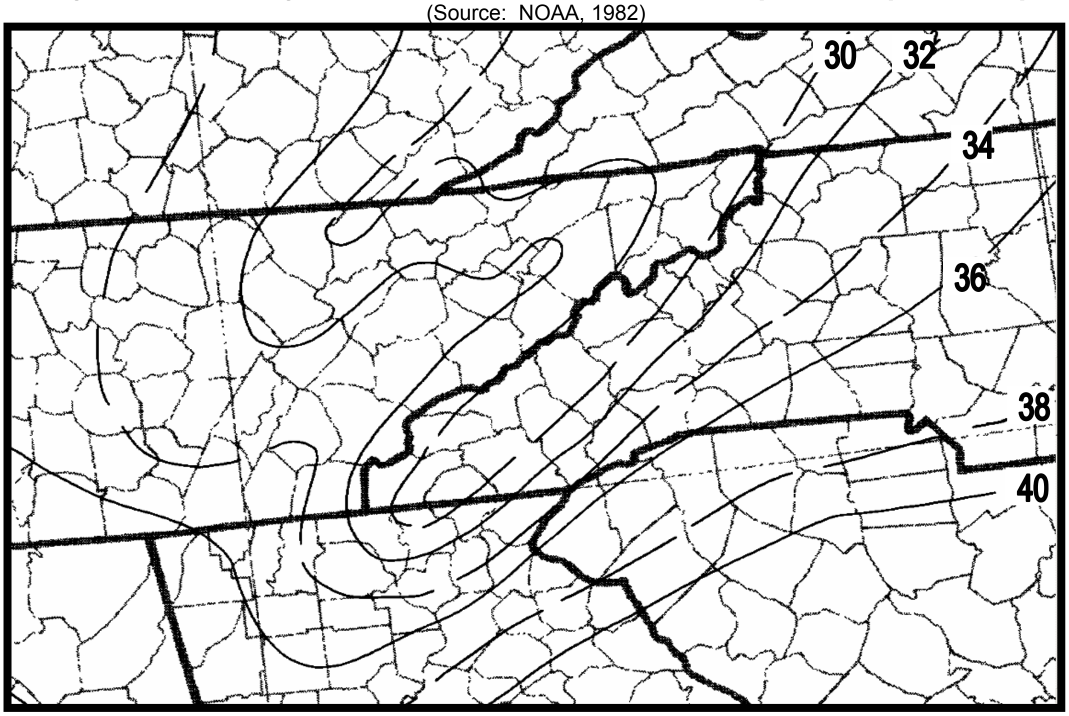
Table 3-7 presents pan evaporation rate distributions for a typical 12-month period based on pan evaporation information from one station in Bristol, TN. Figure 3-3 depicts a map of annual free water surface (FWS) evaporation averages for Tennessee based on a National Oceanic and Atmospheric Administration (NOAA) assessment done in 1982. FWS evaporation differs from lake evaporation for larger and deeper lakes, but can be used as an estimate of it for the type of structural water quality basins and wetlands being designed in northeast Tennessee. Total annual values can be estimated from this map and distributed in accordance with the percentages presented in Table 3-7.

Table 3-7. Pan Evaporation Rates - Monthly Distribution

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.1%	4.0%	7.1%	10.0%	11.9%	12.8%	12.7%	12.0%	10.4%	8.1%	4.6%	3.2%

Figure 3-3. Average Annual Free Water Surface Evaporation (in inches)

(Source: NOAA, 1982)



Evapotranspiration (E_t). Evapotranspiration consists of the combination of evaporation and transpiration by plants. The estimation of E_t for crops is well documented and has become standard practice. However, the estimating methods for wetlands are not documented, nor are there consistent studies to assist the designer in estimating the wetland plant demand on water volumes. Literature values for various places in the United States vary around the free water surface lake evaporation values. Estimating E_t only becomes important when wetlands are being designed and emergent vegetation covers a significant portion of the basin surface. In these cases conservative estimates of lake evaporation should be compared to crop-based E_t estimates and a decision made. Crop-based E_t estimates can be obtained from typical hydrology textbooks or from the web sites mentioned above. A value of zero shall be assumed for E_t unless the wetland design dictates otherwise.

Overflow (O_f) – Overflow is considered as excess runoff, and in water balance design is either not considered since the concern is for average precipitation values, or is considered lost for all volumes above the maximum basin storage. Obviously, for long-term simulations of rainfall-runoff, large storms would play an important part in basin design.

Example 3-7. Water Balance Calculation for Basin

Bristol Farms, a 26-acre site in Bristol, is being developed along with an estimated 0.5-acre surface area basin. There is no baseflow. The desired basin volume to the overflow point is 2 acre-feet. Will the site be able to support the basin volume? From the basic site data we find that the site is 75% impervious with sandy clay loam soil.

Step 1: From Equation 3-5, Rv = 0.015 + 0.0092(75) = 0.71. With the correction factor of 0.9 the watershed efficiency is 0.64.
The annual lake evaporation from Figure 3-3 is about 30 inches.
For a sandy clay loam the infiltration rate is Kh = 0.34 ft/day (Table 3-6).
From a grading plan, it is known that 10% of the total basin area is sloped greater than 4:1.
Monthly rainfall for the local area was found from the website provided above.

Step 2: The table below shows summary calculations for this site for each month of the year.

	Value	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Days per Month	31	28	31	30	31	30	31	31	30	31	30	31
2	Precip. (in)	3.52	3.4	3.91	3.23	4.32	3.89	4.21	3	3.08	2.3	3.08	3.39
3	Evap. Dist. (%)	3.1	4	7.1	10	11.9	12.8	12.7	12	10.4	8.1	4.6	3.2
4	R_0 (ac-ft)	4.88	4.71	5.42	4.48	5.99	5.39	5.84	4.16	4.27	3.19	4.27	4.70
5	P (ac-ft)	0.15	0.14	0.16	0.13	0.18	0.16	0.18	0.13	0.13	0.10	0.13	0.14
6	E (ac-ft)	0.04	0.05	0.09	0.13	0.15	0.16	0.16	0.15	0.13	0.10	0.06	0.04
7	I (ac-ft)	5.01	4.52	5.01	4.85	5.01	4.85	5.01	5.01	4.85	5.01	4.85	5.01
8	Bal. (ac-ft)	-0.02	0.28	0.48	-0.37	1.01	0.54	0.85	-0.87	-0.58	-1.82	-0.51	-0.21
9	Run. Bal. (ac-ft)	0.00	0.28	0.76	0.39	1.40	1.94	2.00	1.13	0.55	0.00	0.00	0.00

Explanation of Table:

1. Days per month
2. Monthly precipitation from website is shown in Table 3-5.

3. Distribution of evaporation by month from Table 3-7.
4. Watershed efficiency of 0.64 x rainfall multiplied x site area and converted to ac-ft.
5. Precipitation volume directly into basin equals precipitation depth times basin surface area Pv=PA.
6. Evaporation volume equals percent evaporation by month (line 3) times 2.5 feet (Figure 3-3 converted to feet) multiplied by pond area (AC).
7. Infiltration volume equals the hydraulic conductivity (Table 36) times the pond area multiplied by the composite hydraulic gradient for the pond times the number of days in the month. I_v = I (days per month).
8. Balance is Lines (4 + 5) minus lines (6 + 7).
9. Running Balance is accumulated total from line 8 keeping in mind that all volume above 2 acre-feet overflows and is lost in the trial design.

It can be seen that for this example the basin has potential to go dry in late fall. This can be remedied in a number of ways including compaction of the basin bottom, placement of a clay or geosynthetic liner, and modification of the basin geometry to decrease the surface area.

3.4 Channel Protection

3.4.1 Minimum Standard

Local ordinances require adherence to the channel protection standard for applicable new development or redevelopments prior to discharge from the site. This requirement shall be implemented in accordance with the **Channel Protection Standard** and associated policies presented in items 1 and 2 below.

1. The runoff volume from the 1-year frequency, 24-hour storm, herein called the Channel Protection Volume (CPv), shall be captured and discharged over no less than a 24-hour period utilizing the design criteria and guidance provided in this manual. In the design of the channel protection control, the 24-hour release period shall be measured from the approximate center-of-mass of inflow to the approximate center-of-mass of outflow.

2. The local jurisdiction may approve downstream channel protection provided by an alternative approach than that stated above if sufficient hydrologic and hydraulic analysis shows that the alternative approach will offer adequate channel protection from erosion.

3.4.2 Estimation of the Channel Protection Volume

The Simplified SCS Peak Runoff Rate Calculation approach can be used for estimation of the channel protection volume (CPv) prior to storage facility design. For the calculation of CPv, this approach must be modified to determine the volume for a 1-year frequency, 24-hour duration design storm event. The calculation procedure is as follows.

<u>Step 1.</u> The 1-year, 24-hour rainfall depth (P, in inches) is determined for the selected location. Consult your local jurisdiction to determine the amount of rainfall to utilize for this calculation.

<u>Step 2.</u> A runoff curve number (CN) is then estimated using standard SCS Runoff Curve Number estimation techniques.

<u>Step 3.</u> The CN value is used to determine the initial abstraction (I_a) from Table 3-4, and the ratio I_a/P is computed.

<u>Step 4.</u> The accumulated runoff (Q_d, inches) can then be calculated using the SCS method.

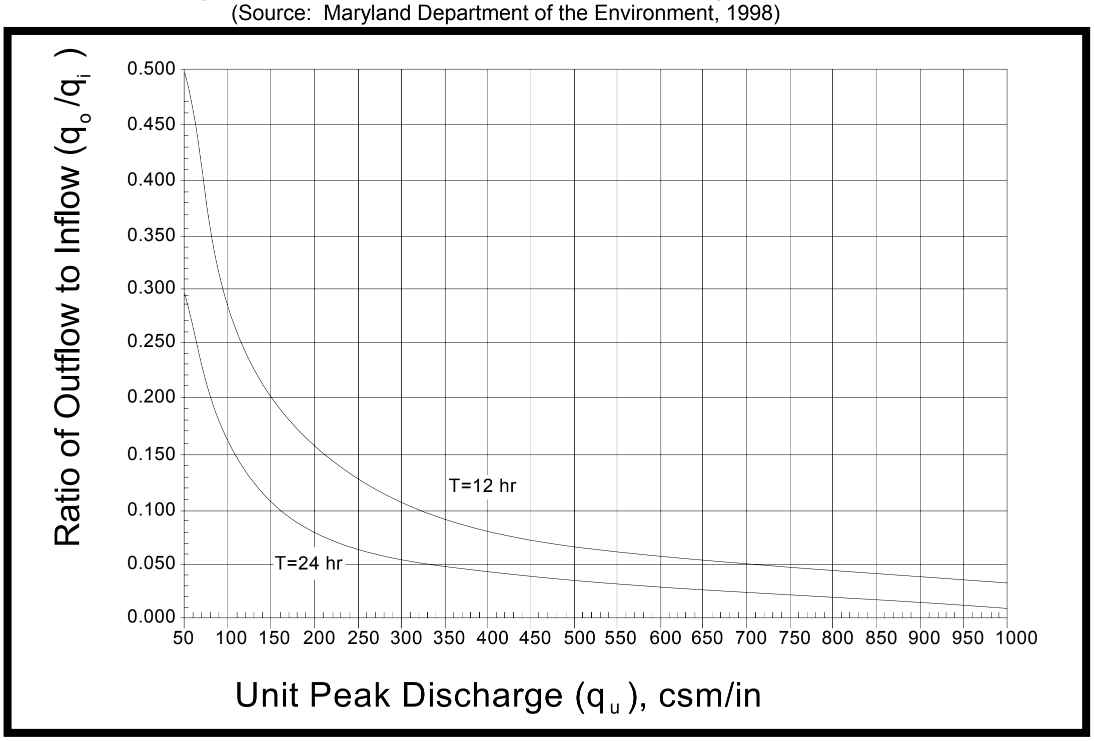
$$Q_d = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad I_a = 0.2S \qquad S = \frac{100}{CN} - 10$$

Step 5. Compute the drainage area time of concentration (t_c) for the post-development land use using standard SCS methods.

Step 6. Use t_c with the ratio I_a/P to obtain the unit peak discharge, q_u, from Figure 3-2 for the Type II rainfall distribution. If the ratio I_a/P lies outside the range shown in the figure, either use the limiting values or use another peak discharge method.

Step 7. Knowing q_u and T (extended detention time, minimum of 24 hours and maximum of 72 hours); the q_o/q_i ratio (peak outflow discharge/peak inflow discharge) can be estimated from Figure 3-4.

Figure 3-4. Detention Time vs. Discharge Ratios
(Source: Maryland Department of the Environment, 1998)



Step 8. V_s/V_r is then determined using the SCS detention basin routing formula of Equation 3-14 or using Figure 3-5. Equation 3-15 is suspect when the expression q_o/q_i approaches the limits of 0.1 and 0.8.

Equation 3-15

$$\frac{V_s}{V_r} = 0.682 - 1.43\left(\frac{q_o}{q_i}\right) + 1.64\left(\frac{q_o}{q_i}\right)^2 - 0.804\left(\frac{q_o}{q_i}\right)^3$$

where:

V_s = required storage volume (acre-feet)
V_r = runoff volume (acre-feet)
q_o = peak outflow discharge (cfs)
q_i = peak inflow discharge (cfs)

Step 9. The required storage volume (CPv in this case) can then be calculated using Equation 3-16. To check the CPv estimate, the volume must be incorporated into a BMP design and the 1-year 24-hour storm routed through the BMP. The CPv is adequate when the 1-year 24-hour design storm is detained for 24 hours, measured from the centroid of the inflow hydrograph to the centroid of the outflow hydrograph.

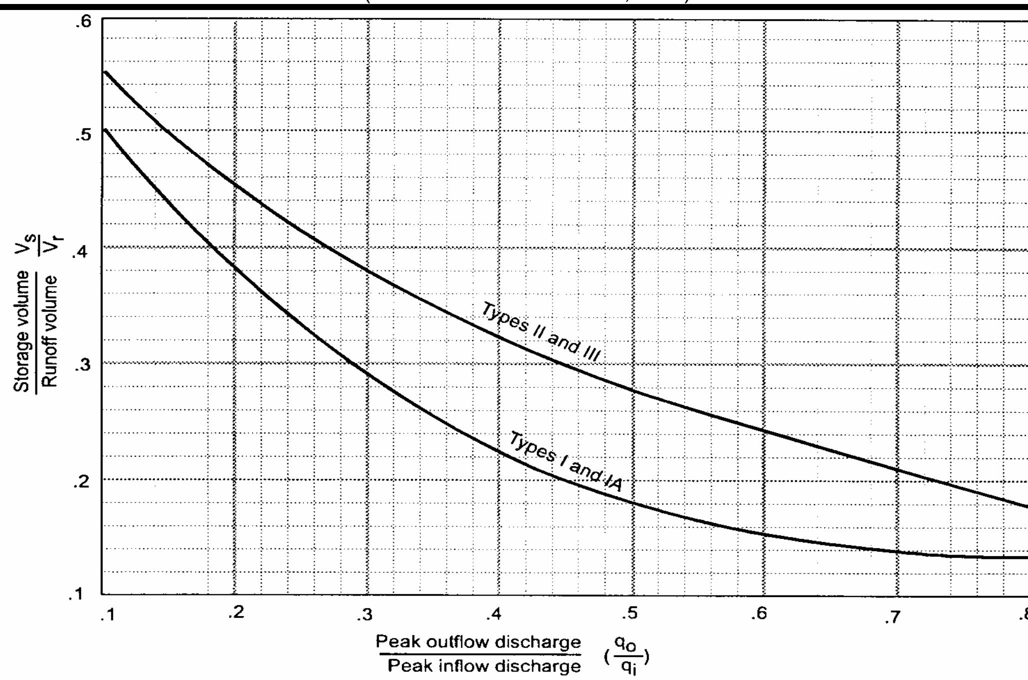
Equation 3-16

$$V_s = \frac{\left(\frac{V_s}{V_r}\right) Q_d A}{12}$$

where:

Vs and Vr are defined above
Qd = the developed runoff depth for the design storm (inches)
A = total drainage area (acres)

Figure 3-5. Approximate Detention Basin Routing for Rainfall Types I, IA, II, and III
(Source: USDA SCS TR-55, 1986)



Example 3-8. Estimation of CPv

Estimate the CPv necessary for a 50-acre wooded watershed, which will be developed as follows:

Forest land - good cover (hydrologic soil group B) = 10 ac
Forest land - good cover (hydrologic soil group C) = 10 ac
Residential with 1/3 acre lots (hydrologic soil group B) = 20 ac
Industrial development (hydrological soil group C) = 10 ac

Other data include the following:
Total impervious area = 18 acres
% of pond and swamp area = 0

Step 1 Determine the rainfall depth (P) for the 1-year 24-hour design storm for the local jurisdiction.
The 1-year, 24 hour rainfall = 2.5 inches = P

Step 2 Determine the weighted runoff coefficient as in the table below.

Dev. #	Area (ac)	% Total	CN	Composite CN[1]
1	10	20	55	11
2	10	20	70	14
3	20	40	72	28.8
4	10	20	91	18.2
Total	50	100	-	72

1 – Composite CN = % Total * CN./100

Step 3 Calculate I_a/P for CN= 72,
I_a = 0.778 (Table 3-4)
I_a/P = (0.778/2.5) = 0.31

Step 4 Calculate Qd for 1-year 24-hour storm using SCS equation
Qd = (2.5-0.778)2/(2.5-0.778+5*0.778) = 0.53 inches

Step 5 Calculate Tc.
Utilizing standard methods for overland, shallow concentrated and channel flow:
Tc = 0.35 hours (assumed)

Step 6 Calculate unit discharge from Figure 3-2 using Tc and Ia/P from previous steps
Unit discharge from Figure 3-2 = q_u (1-year) = 540 csm/in

Step 7 Estimate channel protection volume (CPv = V_S)
Knowing q_u (1-year) = 540 csm/in from Step 6 and T (extended detention time of 24 hours), find q_o/q_i from Figure 3-4.
q_o/q_i = 0.035

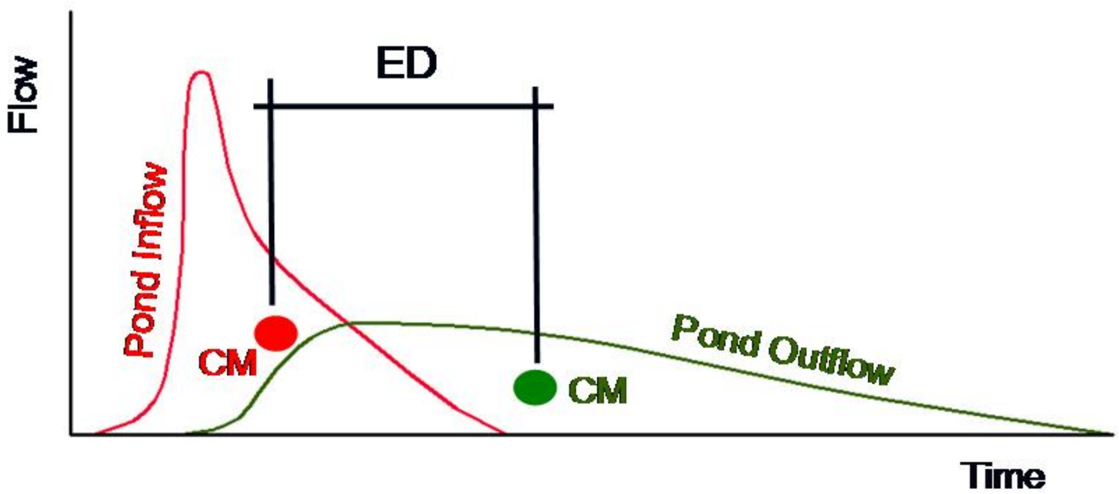
Step 8 Estimate storage/runoff using Equation 3-15,
$V_s/V_r = 0.682 - 1.43(q_o/q_i) + 1.64(q_o/q_i)^2 – 0.804(q_o/q_i)^3$
$V_s/V_r = 0.682 - 1.43(0.035) + 1.64(0.035)^2 – 0.804(0.035)^3 = 0.63$

Step 9 The necessary detention volume is then calculated using Equation 3-16
CPv = V_s ≈ (Vs/Vr)*Qd*A/12 = (0.63)(0.53)(50)/12 ≈ 1.39 ac-ft

3.4.3 The Design of Channel Protection Outlets

The previous example provides an estimate of the volume required for channel protection storage. In order for the downstream channel to be protected, an orifice must next be sized to accomplish the detention criteria. The purpose of channel protection outlets is to prevent the erosive channel-forming flows that occur during the 1 to 2 year storm. This purpose is accomplished by extending the detention of the 1-year 24-hour design storm to 24 hours. The detention time is measured from the centroid of the inflow hydrograph to the centroid of the outflow hydrograph as shown in Figure 3-6.

Figure 3-6. Illustration of the Channel Protection Standard



3.4.3.1 Channel Protection Outlet Sizing

Channel protection outlets, then, must be sized using hydrograph routing techniques. The channel protection volume estimated in Section 3.4.2 will have a channel protection outlet placed at the bottom of it. The size of the outlet can only be estimated initially. Routing the 1-year 24-hour inflow hydrograph through the pond will provide an outflow hydrograph. If the centroid to centroid detention time is less than 24 hours, the channel protection orifice must be made smaller. The water quality orifice may preclude reaching the CPv 24 hour detention time, in which case, the water quality orifice must be made smaller. The water quality and channel protection orifices can be combined so long as both water quality and channel protection criteria are met.

3.5 Downstream Impact Analysis

3.5.1 Background

Local jurisdiction's stormwater design criteria may require the design to control peak discharges at the outlet of a site, such that the post-development peak discharge does not exceed the pre-development peak discharge. Typically, this peak discharge control is achieved through construction of one or more on-site detention facilities. Peak discharge control does not always provide effective water quantity control from the site, and may actually exacerbate flooding problems downstream of the site. Moreover, master plans have shown that a development site's location within a watershed may preclude the requirement for overbank flood control from a particular site.

A major reason for negative impacts due to stormwater detention facilities involves the timing of the peak discharge from the site in relation to the peak discharges in the receiving stream and/or its tributaries. If detention structures are indiscriminately placed in a watershed without consideration of the relative timing of downstream peak discharges, the structural control may actually increase the peak discharge downstream. An example of this situation is presented in Figure 3-7, which shows a comparison of the total downstream flow on a receiving stream (after development) with and without detention controls. In Figure 3-7, the smaller dashed-dot and solid lines denote the runoff hydrograph for a development site with and without detention, respectively. These runoff hydrographs will combine with a larger runoff hydrograph of the receiving stream (not shown). The combined discharges from the site and receiving stream are shown in the larger solid and dashed lines.

Figure 3-7. Potential Effect of On-Site Detention on Receiving Streams

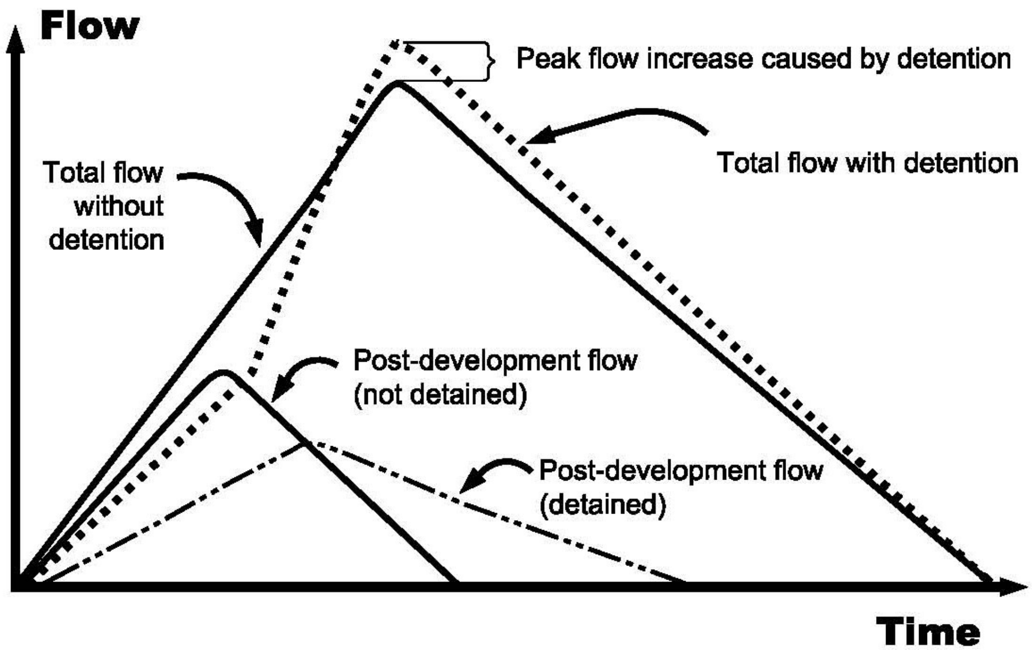
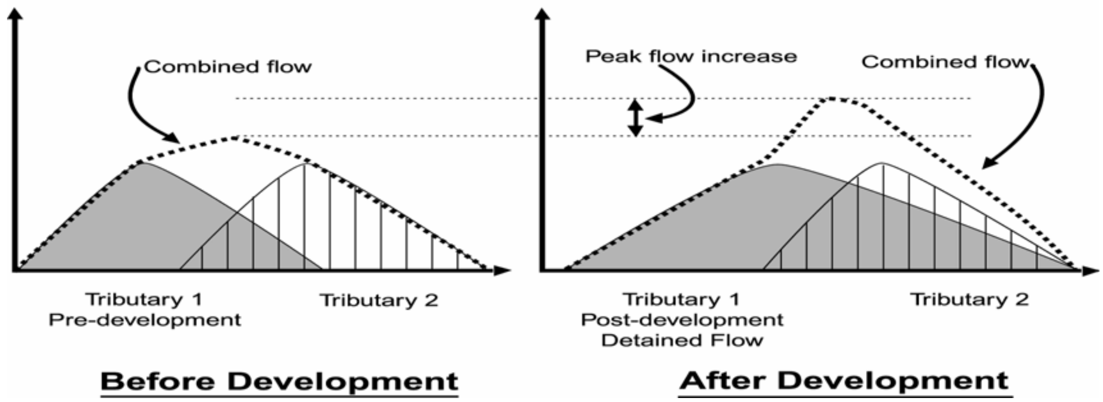


Figure 3-7 conveys a possible consequence of detention. The post-development flow from the site is reduced as required by flood protection design criteria to result in the detained flow (the smaller dashed-dot hydrograph). However, the timing of the peak discharge for the detained post-development flow, while reduced in magnitude, corresponds more closely with the timing of the peak discharge of the receiving stream (not shown) than the peak discharge of the post-development flow that was not detained. Therefore, the combination of the detained flow with the flow in the receiving stream is actually higher than would occur if no detention were required, as shown in the larger dashed hydrograph. Hence, there is a peak flow increase that is caused by detention.

Poor peak discharge timing can have an even greater impact when one considers all the developments located in a watershed and the cumulative effects of increases in runoff volume and the duration of high volume runoff in the channel, as well as peak discharge timing. Even if peak discharges are handled effectively at the site level and immediately downstream, the longer duration of higher flows due to the increased volume from many developments located on or near a stream may combine with downstream tributaries and receiving streams to dramatically increase the downstream peak flows.

Figure 3-8 illustrates this concept. The figure shows the pre- and post-development hydrographs at the confluence of two tributaries. Development occurs, meets the local flood protection criteria (i.e., the post-development peak flow is equal to the pre-development peak flow at the outlet from the site), and discharges to Tributary 1. When the post-development detained flow from Tributary 1 combines with the first downstream tributary (Tributary 2), it causes a peak flow increase when compared to the pre-development combined flow. This is due to the increased volume and timing of runoff from Tributary 1, relative to the peak flow and timing in Tributary 2. In this case, the detention volumes on Tributary 1 would have to have been increased to account for the downstream timing of the combined hydrographs to mitigate the impact of the increased runoff volume.

Figure 3-8. Potential Effect of Cumulative Detention Basins



Potential problems such as those described above are quite common, but can be avoided through the use of a stormwater master plan and/or downstream analysis of the effects of a planned development. Studies have shown that if a developer is required to assess the impacts of a development downstream to the point where the developed property is 10% of the total drainage area, and there are no adverse impacts (i.e., stream peak discharge increases), then there is assurance that there will not be significant increases in flooding problems further downstream. For example, for a 10-acre site, the assessment would have to take place down to a point where the total accumulated drainage area is 100 acres.

While this assessment does require some additional labor on the part of the design engineer, it allows smart stormwater management within a watershed. The assessment provides the developer, the local jurisdiction and downstream property owners with a better understanding (and corresponding documentation) of the potential downstream impacts of development. In turn, this information identifies those developments for which waivers or reductions in the flood protection requirements may prove beneficial.

3.5.2 Minimum Standard

Policies pertaining to the downstream impact analysis, if required by the local jurisdiction, are listed below.

1. Downstream impact analysis shall be required for all developments and redevelopments for which a water quality management plan is required. The analysis shall determine if the proposed development or redevelopment causes an increase in peak discharge as compared to pre-development runoff rates for the same site, or has the potential to cause downstream channel and streambank erosion. This analysis must be done for all storm events that are required for peak flow control by the local jurisdiction. Peak flows must be analyzed at the outfall(s) of the site, and at each downstream tributary junction and each public or major private downstream stormwater conveyance structure to the point(s) in the stormwater system where the area of the portion of the site draining into the system is less than or equal to 10% of the total drainage area above that point.

2. If the downstream impact analysis shows that the development or redevelopment causes an increase in peak discharges, downstream flood protection shall be provided such that the calculated peak discharges for the locally specified storm events after development of the site are not greater than that which would result from the same duration storms in the same downstream analysis area prior to development or redevelopment. These criteria must be applied throughout the 10% downstream analysis area.

3. Downstream flood protection can be provided by downstream conveyance improvements and/or purchase of flow easements in lieu of peak discharge controls subject to prior approval

by the local jurisdiction and satisfaction of the following requirements:

(1) Sufficient hydrologic and hydraulic analysis must be presented that shows that the alternative approach will offer adequate protection from downstream flooding for all potentially affected downstream property owners.

(2) The applicant is responsible for submittal and approval of any necessary CLOMR prior to construction, and a LOMR upon completion of construction.

(3) The applicant is responsible for all State and Federal permits that may be applicable to the site including TDEC NPDES and ARAP permits, US Army Corps of Engineers Section 404 permits, and TVA Section 26A permits.

4. Developments and redevelopments that do not cause an increase in peak discharges are not exempt from conformance with the minimum standards for water quality treatment (WQv) and channel protection (CPv), presented earlier in this chapter.
5. The downstream analysis should be performed after any WQv reductions for better site design practices have been taken into consideration in the calculation of peak discharges leaving the site. While there are no reductions for flood protection criteria, the use of better site design practices will inherently reduce runoff volumes and potentially reduce post-development peak discharges, both on-site and downstream of the site.
6. The data and results of the downstream analysis must be presented to the local jurisdiction as part of the water quality management plan.

Typical steps in the application of the ten-percent rule are:

1. Using a topographic map determine the lower limit of the "zone of influence" (i.e., the 10% point), and determine all 10% rule comparison points (at the outlet of the site and at all downstream tributary junctions or other points of interest).
2. Using a hydrologic model determine the pre-development peak discharges for the storms specified by the local jurisdiction and the timing of those peaks at each tributary junction beginning at the pond outlet and ending at the next tributary junction beyond the 10% point.
3. Change the site land use to post-development conditions and determine the post-development peak discharges and timing for the same storms. Design the structural control facility such that the post-development peak discharges from the site <u>for all storm events</u> do not increase the pre-development peak discharges at the outlet of the site and at each downstream tributary junction and each public or major private downstream stormwater conveyance structure located within the zone of influence.
4. If post-development conditions do increase the peak flow within the zone of influence, the structural control facility must be redesigned or conveyance improvements/flow easements may be allowed by the local jurisdiction (see item 3 in the previous section).

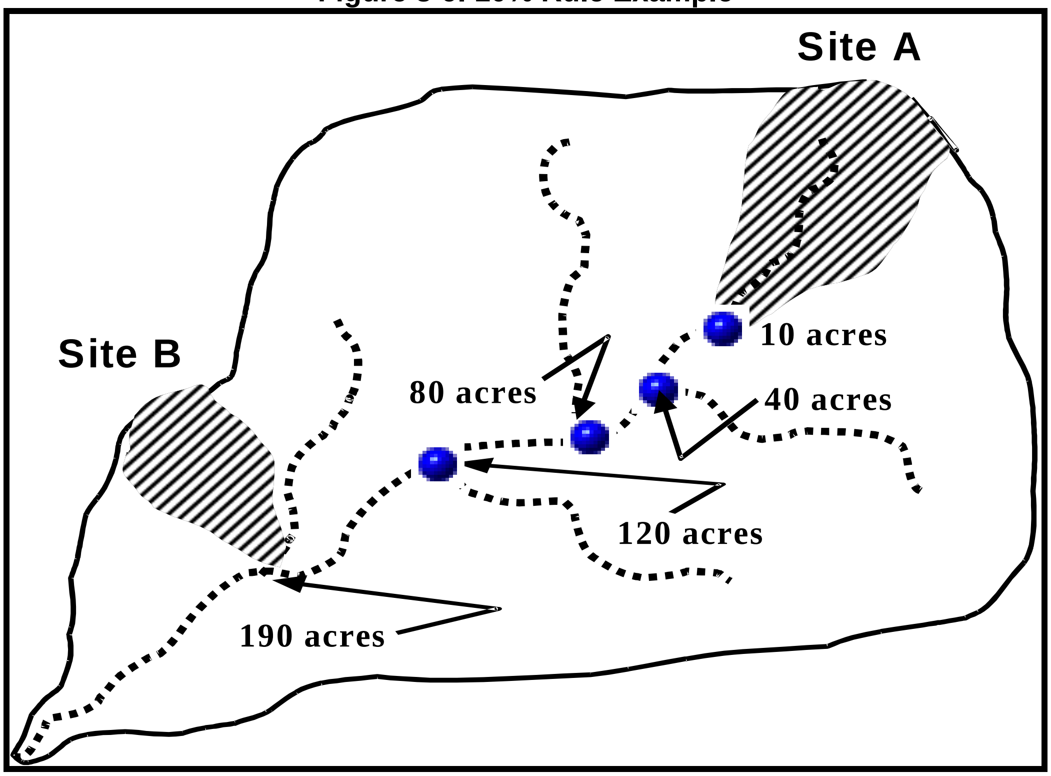
Example 3-9. Ten Percent Rule Example

Figure 3-9 illustrates the concept of the ten-percent rule for two sites in a watershed.

Site A is a development of 10 acres, all draining to a wet ED stormwater pond. Looking downstream at each tributary in turn, it is determined that the analysis should end at the tributary marked "120 acres." The 100-acre (10%) point is in between the 80-acre and 120-acre tributary junction points.

The designer constructs a simple HEC-1 (HEC-HMS) model of the 120-acre areas using single existing condition sub-watersheds for each tributary. Key detention structures existing in other tributaries must be modeled. An approximate curve number is used since the *actual* peak flow is not the key for initial analysis; only the increase or decrease is important. The accuracy in curve number determination is not as significant as an accurate estimate of the time of concentration. Since flooding is an issue downstream, the pond is designed (through several iterations) until the peak flow does not increase at junction points downstream to the 120-acre point.

Figure 3-9. 10% Rule Example



Site B is located downstream at the point where the total drainage area is 190 acres. The site itself is only 6 acres. The first tributary junction downstream from the 10% point is the junction of the site outlet with the stream. The total 190 acres is modeled as one basin with care taken to estimate the time of concentration for input into the hydrologic model of the watershed. The model shows that a detention facility, in this case, will actually <u>increase</u> the peak flow in the stream.

3.6 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

Ferguson, B. and Debo, T. *On-Site Stormwater Management.* 1990.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

NOAA. *Evaporation Atlas for the Contiguous 48 United States.* NOAA Technical Report NWS 33, 1982.

Pitt, Robert. *Small Storm Hydrology.* Unpublished report. Department of Civil Engineering, University of Alabama at Birmingham, 1994.

U. S. Department of Agriculture, Soil Conservation Service, Engineering Division, 1986. *Urban Hydrology for Small Watersheds. Technical Release 55 (TR-55)*.

Virginia Department of Conservation and Recreation. *Virginia Stormwater Management Handbook, First Edition,* 1999.

Table of Contents

CHAPTER 4 — DESIGN AND MAINTENANCE OF STRUCTURAL BMPS

Chapter 4 - List of Figures

Chapter 4 - List of Tables

Chapter 4 - List of Equations

CHAPTER

4

DESIGN AND MAINTENANCE OF STRUCTURAL BMPS

Structural stormwater best management practices (BMPs) are engineered facilities that are intended to treat stormwater runoff. This chapter provides detailed descriptions and design specifications for the structural stormwater BMPs that can be used to address the minimum stormwater management standards outlined in Chapter 1 and the design criteria cited in Chapter 3.

Sites must be designed and constructed so that the BMPs, used:

- treat the Water Quality Volume (WQv);
- control the Channel Protection Volume (CPv); and,
- create no adverse impact on downstream properties.

4.1 Design Standards Policy

The State of Tennessee's NPDES Phase II regulation requires regulated municipalities to implement a post-construction stormwater treatment program. To comply with this regulation, local governments require that stormwater runoff be treated for pollutants prior to discharge from the site. Chapters 1 and 3 of this manual sets the minimum design standard for stormwater treatment as removal of 80% of the average annual post-development total suspended solids (TSS) load. The structural BMPs presented in this chapter, used alone or in series, can be used to meet this minimum design standard. For purposes of compliance with local and State regulations, it is presumed that developments and redevelopments are meeting the 80% TSS removal standard so long as water quality management systems are designed, constructed, and maintained in accordance with the design criteria and specifications discussed in this manual.

Therefore, the local jurisdictions require that all of the structural BMPs presented in this section be designed, constructed and maintained in accordance with the criteria, standards, and specifications presented in this manual. Proprietary, new, and other BMPs not included in this manual may be approved by the local jurisdiction for treatment of stormwater quality on a case-by-case basis provided that the conditions outlined in Chapter 2 of this manual are met.

4.2 BMP Description and Selection Information

The structural stormwater BMPs recommended in this manual have been placed into two categories, general application and limited application, based upon each generalized acceptance criteria set by the local jurisdictions. These categories are described below.

4.2.1 General Application BMPs

A listing of general application BMPs can be found in Table 4-1 below. The local jurisdictions will accept these BMPs for use with a wide variety of land uses and development types. General application BMPs have a demonstrated ability to treat the WQv and many are presumed able to achieve the 80% TSS removal standard when designed, constructed and maintained in accordance with recommended specifications. Several of the general application BMPs can also be designed to comply with other stormwater criteria such as for downstream channel protection. Developers and engineers are encouraged to use the general application BMPs wherever feasible and practical. A detailed discussion of each of the general application BMPs, as well as design criteria and procedures can be found later in this chapter.

Table 4-1. Descriptions of General Application BMPs

Structural BMP	Description
Stormwater Basins • Wet Basin • Wet ED Basin • Micropool ED Basin • Multiple Basin Systems	Stormwater basins are constructed stormwater retention basins that have a permanent pool (or micropool) of water. Runoff from each rain event is detained and treated in the pool. ED = Extended Detention. ED is the detention of stored runoff for a minimum of 24 hours.
Detention Basins • Dry Detention Basin • Dry ED Basin	Dry detention basins and dry extended detention (ED) basins are surface facilities intended to provide for the temporary storage of stormwater runoff to reduce downstream water quantity impacts and will have to be combined with another BMP to achieve the 80% TSS removal goal.
Stormwater Wetlands • Shallow Wetland • ED Shallow Wetland • Basin/Wetland Systems • Pocket Wetland	Stormwater wetlands are constructed wetland systems used for stormwater management. Stormwater wetlands consist of a combination of shallow marsh areas, open water and semi-wet areas above the permanent water surface.
Bioretention Areas	Bioretention areas are shallow stormwater basins or landscaped areas which utilize engineered soils and vegetation to capture, infiltrate and treat stormwater runoff. Runoff may be returned to the conveyance system, or allowed to partially infiltrate into the soil.
Sand Filters • Surface Sand Filter • Perimeter Sand Filter	Sand filters are multi-chamber structures designed to treat stormwater runoff through filtration, using a sand bed as its primary filter media. Filtered runoff may be returned to the conveyance system, or allowed to partially infiltrate into the soil.
Infiltration Trench	An infiltration trench is an excavated trench filled with stone aggregate used to capture and allow infiltration of stormwater runoff into the surrounding soils from the bottom and sides of the trench.
Enhanced Swales • WQ Dry Swale • Wet Swale	Enhanced swales are vegetated open channels that are explicitly designed and constructed to capture and treat stormwater runoff within dry or wet cells formed by check dams or other means.
Biofilters • Filter Strip • Grass Channel	Both filter strips and grass channels provide “biofiltering” of stormwater runoff as it flows across the grass surface. However, by themselves these controls cannot meet the 80% TSS removal performance goal. Consequently, both filter strips and grass channels should only be used as pretreatment measures or as part of a treatment train approach. Grass channels are open channel practices that are not designed specifically for water quality.
Modular Porous Paver Systems and Porous Pavement/Concrete	Porous surfaces are permeable pavement surfaces with an underlying stone reservoir to temporarily store surface runoff before it infiltrates into the subsoil. These practices are considered source control BMPs rather than treatment BMPs. Areas where porous surfaces have been applied are included in the WQv calculations as pervious surfaces, rather than impervious surfaces. Porous concrete is the term for a mixture of course aggregate, portland cement and water that allows for rapid infiltration of water. Modular porous paver systems consist of open void paver units laid on a gravel subgrade. Both porous concrete and porous paver systems provide water quality and quantities benefits, but may have high workmanship and maintenance requirements.

4.2.2 Limited Application BMPs

Limited application BMPs will be allowed only when the use of general application BMPs is not feasible because special site or design conditions prohibit their use and will be approved for use in the local jurisdictions on a site-by-site basis. In general, limited application BMPs are intended to address hotspot or specific land use constraints or conditions requiring pretreatment, and may have high installation costs or special maintenance requirements that may preclude their use for most general applications. Limited application BMPs are typically used for water quality treatment only and do not provide additional control for channel or flood protection. Limited application BMPs should be considered primarily for commercial, industrial or institutional developments.

Table 4-2 lists the limited application BMPs, along with the rationale for limited use. These structural BMPs are recommended for use with particular land uses and densities, to meet certain water quality requirements, for limited usage on larger projects, or as part of a stormwater treatment train. A detailed discussion of each of the limited application BMPs, as well as design criteria and procedures can be found later in this chapter.

Table 4-2. Descriptions of Limited Application BMPs

Structural BMP	Description and Rationale for Limited Use
Filtering Practices • Organic Filter	Organic filters are surface sand filters where organic materials such as a leaf compost or peat/sand mixture are used as the filter media. These media may be able to provide enhanced removal of some contaminants, such as heavy metals and nutrients. Given their potentially high maintenance requirements, they should only be used in environments that warrant their use.
• Underground Sand Filter	Underground sand filters are sand filter systems located in an underground vault. These systems should only be considered for extremely high density or space-limited sites.
Wetland Systems • Submerged Gravel Wetlands	Submerged gravel wetlands systems use wetland plants in a submerged gravel or crushed rock media to remove stormwater pollutants. These systems should only be used in mid- to high-density environments where the use of other structural controls may be precluded. The long-term maintenance burden of these systems is uncertain.
Chemical Treatment • Alum Treatment	Alum treatment provides for the removal of suspended solids from stormwater runoff entering a wet basin by injecting liquid alum. Alum treatment should only be considered for large-scale projects where high water quality is desired and where other BMPs do not provide the level of pollutant removal required for the receiving water.
Proprietary Systems • Commercial Stormwater BMPs	Proprietary BMPs are manufactured structural control systems available from commercial vendors designed to treat stormwater runoff and/or provide water quantity control. Proprietary systems often can be used on small sites and in space-limited areas, as well as in pretreatment applications. However, proprietary systems are often more costly than other alternatives, may have high maintenance requirements, and often lack adequate independent performance data, particularly for use in local conditions.
Gravity (oil-grit) Separator	Gravity separators, (also called hydrodynamic BMPs) use the movement of stormwater runoff through a specially designed structure to remove target pollutants. They are typically used on smaller impervious commercial sites and urban hotspots. These BMPs typically do not meet the 80% TSS removal performance goal, and therefore, should only be used as a pretreatment measure and as part of a treatment train approach.

4.2.3 Pollutant Removal Capabilities

Research has shown that the use of the structural BMPs discussed in this chapter will have benefits for the removal of TSS and other pollutants (i.e., phosphorous, nitrogen, fecal coliform and heavy metals). The ability for both general and limited application BMPs to remove pollutants varies by structural BMP type and by pollutant type. Pollutant removal capabilities for a given BMP are based on a number of factors including the physical, chemical and/or biological processes that take place in the BMP and the design and sizing of the facility. In addition, pollutant removal efficiencies for the same BMP type and facility design can vary widely depending on the tributary land use and area, incoming pollutant concentration, rainfall pattern, time of year, maintenance frequency and numerous other factors.

Table 4-3 provides design removal efficiencies assigned to each of the general and limited application BMPs. It should be noted that these values are median pollutant reduction percentages for design purposes that have been derived from existing sampling data, modeling and research. A structural BMP design may be capable of exceeding these performances; however, the values in the table are considered median values that can be assumed to be achieved when the structural BMP is sized, designed, constructed and maintained in accordance with recommended specifications in this manual.

Where the pollutant removal capabilities of an individual structural stormwater BMP are not sufficient for a given site application, additional controls may be used in series in a "treatment train" approach. More detail on the use of stormwater BMPs in series is provided later in this chapter.

4.2.4 Screening Process for General Application BMPs

Outlined below is a process used in the selection of general application BMPs. This process is intended to assist the site developer and design engineer in determining the most appropriate structural BMP for a development site, and to provide guidance on factors to consider in their location. The goal of 80% TSS removal is the primary factor in the selection process of BMPs or BMP treatment trains. Information on selection factors related to pollutants other than TSS are provided for informational purposes, and may be useful in the future depending upon local, state and federal water quality regulations at that time.

In general, the following four criteria should be evaluated in order to select the appropriate structural BMP(s) or group of BMPs for a development:

- stormwater treatment suitability;
- water quality performance;
- site applicability;
- implementation considerations.

In addition, for a given site, the following factors should be considered and any specific design criteria or restrictions need to be evaluated:

- physiographic factors;
- soils;
- special watershed or stream considerations.

Finally, environmental regulations that may influence the location of a structural BMP on site, or may require a permit, need to be considered.

Table 4-3. Design Pollutant Removal Efficiencies (in %) for Structural BMPs

Structural BMP	TSS	Total P[1]	Total N[2]	Fecal Coliform	Metals
General Application Structural BMPs					
Stormwater Basins (Wet ED Basin, Micropool ED Basin, and Multiple Basin Systems)	80	55	30	70*	50
Conventional Dry Detention Basin	10	---	---	---	---
Dry Extended Detention Basin	60	35	25	---	25
Stormwater Wetlands (Shallow Wetlands, ED Wetlands, Basin/Wetland System, Pocket Wetland)	80	45	30	70*	50
Bioretention Areas	85	60	50	---	80
Sand Filters	80	50	30	40	50
Infiltration Trench	90	60	60	90	90
Water Quality (WQ) Dry Swale	90	50	50	---	40
Wet Swale	75	25	40	---	20
Filter Strip	50	20	20	---	40
Grass Channel[3]	30	25	20	---	30
Modular Porous Paver Systems and Porous Pavement/Concrete	**	**	**	**	**
Limited Application Structural BMPs					
Organic Filter	80	60	40	50	75
Underground Sand Filter	80	50	25	40	50
Submerged Gravel Wetland	80	50	20	70	50
Alum Treatment	90	80	60	90	75
Proprietary Systems	***	***	***	***	***
Gravity (oil-grit) Separator	30	5	5	---	---

1 Total phosphorus
2 Total nitrogen
3 Refers to open channel practices not designed specifically for water quality.
* If no resident waterfowl population is present.
** These practices are source controls and are not designed as pollutant removal devices.
*** The performance of specific proprietary commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data.
--- Insufficient data to provide design removal efficiency.

Guidance on a selection process for comparing and evaluating various general application structural stormwater BMPs using two screening matrices and a list of location and permitting factors is presented below. These tools are provided to assist the design engineer in selecting the subset of structural BMPs that will meet the stormwater management and design objectives for a development site or project.

Step 1: Evaluate Overall Applicability

Through the use of Table 4-4, the site designer evaluates and screens the overall applicability of the full set of general application structural BMPs as well as the constraints of the site in question. The discussion following the table presents an explanation of the various screening categories and individual characteristics used to evaluate the structural BMPs.

<u>Stormwater Management Suitability</u>

The first columns of Table 4-4 examine the capability of each structural BMP option to provide water quality treatment, downstream channel protection and flood protection. A blank entry means that the structural BMP cannot or is not typically used to meet the aforementioned criteria. This does not necessarily mean that it should be eliminated from consideration, but rather is a reminder that more than one structural BMP may be needed at a site (e.g., a bioretention area used in conjunction with dry detention storage).

> *Ability to treat the Water Quality Volume (WQv).* This indicates whether a structural BMP provides treatment of the WQv and provides the TSS reduction amount assigned to each BMP type.
>
> *Ability to provide Channel Protection (CPv)*. This indicates whether the structural BMP can be used to provide the extended detention of the CPv. The presence of a check mark indicates that the structural control can be used to meet CPv requirements. A diamond indicates that the structural control may be sized to provide channel protection in certain situations, for instance on small sites.
>
> *Ability to provide Flood Protection*. This indicates whether a structural BMP can be used to meet flood protection criteria. The presence of a check mark indicates that the structural control can be used to provide peak reduction of the locally regulated storm event.

<u>Relative Water Quality Performance</u>

The second group of columns in Table 4-4 provides an overview of the pollutant removal performance of each structural control option, when designed, constructed and maintained according to the criteria and specifications in this manual.

> *Ability to provide TSS Removal*. This column indicates the capability of a structural BMP to remove TSS from runoff.
>
> *Ability to accept Hotspot Runoff*. This last column indicates the capability of a structural BMP to treat runoff from designated hotspots. Hotspots are land uses or activities with higher potential pollutant loadings. Examples of hotspots might include: gas stations, convenience stores, marinas, public works storage areas, vehicle service and maintenance areas, commercial nurseries, and auto recycling facilities. A check mark indicates that the structural BMP may be used on hotspot site. However, it may have specific design restrictions. Please see Section 4.3 for the specific design criteria of the structural BMP for more details.

Table 4-4. General Application BMP Screening Matrix – Overall BMP Applicability

STRUCTURAL BMP CATEGORY	STRUCTURAL BMP	STORMWATER TREATMENT SUITABILITY			WATER QUALITY PERFORMANCE*		SITE APPLICABILITY					IMPLEMENTATION CONSIDERATIONS			
		Water Quality	Channel Protection	Flood Protection	TSS / Sediment Removal Rate	Hotspot Application	Drainage Area (acres)	Space Req'd (% of tributary imp. Area)	Site Slope	Minimum Head Required	Depth to Water Table	Residential Subdivision Use	High Density / Ultra-Urban	Capital Cost	Maintenance Burden
Stormwater Basins	Wet Basin	✓	✓	✓	80%		25 min**	2-3%	15% max	6 to 8 ft	2 feet, if hotspot or aquifer	✓		Low	Low
	Wet ED Basin	✓	✓	✓								✓		Low	Low
	Micropool ED Basin	✓	✓	✓			10 min**					✓		Low	Moderate
	Multiple Basins	✓	✓	✓			25 min**					✓		Low	Low
Detention Basins	Extended Detention	✓	✓	✓	60%		No min	4-5%	15% max		2 feet min	✓		Low	Low
	Conventional Detention	✓	✓	✓	10%		No min	4-5%	15% max		2 feet min	✓		Low	Low
Stormwater Wetlands	Shallow Wetland	✓	✓	✓	80%		25 min	3-5%	8% max	3 to 5 ft	2 feet, if hotspot or aquifer	✓		Moderate	Moderate
	Shallow ED Wetland	✓	✓	✓								✓		Moderate	Moderate
	Basin/Wetland	✓	✓	✓						6 to 8 ft		✓		Moderate	Moderate
	Pocket Wetland	✓	✓				5 min			2 to 3 ft	below WT	✓	✓	Moderate	High
Bioretention	Bioretention Areas	✓	♦		85%		5 max***	5%	6% max	5 ft	2 feet	✓	✓	Moderate	Moderate
Sand Filters	Surface Sand Filter	✓	♦		80%	✓	10 max***	2-3%	6% max	5 ft	2 feet		✓	High	High
	Perimeter Sand Filter	✓	♦			✓	2 max***			2 to 3 ft			✓	High	High
Infiltration	Infiltration Trench	✓	♦		90%		5 max	2-3%	6% max	1 ft	4 feet	✓	✓	High	High
Enhanced Swales	Dry Swale	✓	♦		90%		5 max	10-20%	4% max	3 to 5 ft	2 feet	✓		Moderate	Low
	Wet Swale	✓	♦		75%		5 max			1 ft	below WT	✓		High	Low
Biofilters	Filter Strip	✓			50%		2 max	20-25%	2-6% max		2-4 feet	✓		Low	Moderate
	Grass Channel	✓			30%		5 max	10-20%	4% max		2 feet	✓		Low	Low
Modular Porous Paver Systems and Porous Pavement/Concrete	Porous Pavers, Pavement and Concrete		✓		**		5 max	varies	5%	2 ft	4 feet	✓	✓	Moderate	High

✓ This BMP meets suitability criteria.

♦ This BMP can be incorporated into the structural control in certain situations.

* TSS pollutant removal rates must be used for design purposes. See Volume 1 Chapter 3 for guidance on calculating the % TSS removal for a development site.

** Smaller drainage areas may be approved by the local jurisdiction with adequate water balance and anti-clogging device.

*** The use of this BMP for larger drainage areas may be approved by the local jurisdiction if design calculations show that the BMP will achieve its design intentions given a larger drainage area.

<u>Site Applicability</u>

The third group of columns in Table 4-4 provides an overview of the specific site conditions or criteria that must be met for a particular structural BMP to be suitable. In some cases, these values are recommended values or limits that can be exceeded or reduced with proper design or depending on specific circumstances. Refer to the specific criteria section of the structural BMP in Section 4.3 for more details.

Drainage Area. This column indicates the approximate minimum or maximum drainage area that is considered suitable for the structural BMP. The local jurisdiction may approve exceptions to the drainage area maximum or minimum depending on the site conditions and the structural BMP(s) being proposed. The drainage areas indicated for basins and wetlands should not be considered inflexible limits, and may be increased or decreased depending on water availability (baseflow or groundwater), the mechanisms employed to prevent outlet clogging, or design variations used to maintain a permanent pool (e.g., liners).

Space Required (Space Consumed). This comparative index expresses how much space a structural BMP typically consumes at a site in terms of the approximate area required as a percentage of the area draining to the control.

Slope. This column evaluates the effect of slope on the structural BMP. Specifically, the slope restrictions refer to how flat the area where the facility is installed must be and/or how steep the contributing drainage area or flow length can be.

Minimum Head. This column provides an estimate of the minimum elevation difference needed at a site (from the inflow to the outflow) to allow for gravity operation within the structural BMP.

Water Table. This column indicates the minimum depth to the seasonally high water table from the bottom or floor of a structural BMP.

<u>Implementation Considerations</u>

The last group of columns of Table 4-4 provides additional considerations for the applicability of each structural BMP option.

Residential Subdivision Use. This column identifies whether or not a structural BMP is suitable for typical residential subdivision development (not including high-density or ultra-urban areas).

Ultra-Urban. This column identifies those structural BMPs that are appropriate for use in very high-density (ultra-urban) areas, or areas where space is a premium.

Construction Cost. The structural BMPs are ranked according to their relative construction cost per impervious acre treated as determined from cost surveys.

Maintenance. This column assesses the relative maintenance effort needed for a structural stormwater BMP, in terms of three criteria: frequency of scheduled maintenance, chronic maintenance problems (such as clogging) and reported failure rates. It should be noted that all structural BMPs require routine inspection and maintenance.

Step 2: Specific Criteria

Table 4-5 provides an overview of various design criteria, specifications, and exclusions for a structural BMP that may be present due to a site's general physiographic character, soils, or location in a watershed with special water resources considerations.

Table 4-5. General Application BMP Screening Matrix – Specific Criteria

STRUCTURAL BMP	PHYSIOGRAPHIC FACTORS			SOILS
	Low Relief	High Relief	Karst	
Stormwater Basins	Limit maximum normal pool depth to about 4 feet (dugout) Providing basin drain can be problematic	Embankment height restrictions	Require poly or clay liner Max ponding depth Geotechnical tests	"A" soils may require basin liner "B" soils may require infiltration testing
Detention Basins	✸	Embankment height restrictions	Require poly or clay liner Max ponding depth Geotechnical tests	"A" soils may require basin liner "B" soils may require infiltration testing
Stormwater Wetlands	✸	Embankment height restrictions	Require poly-liner Geotechnical tests	"A" soils may require basin liner
Bioretention & Sand Filters	Several design variations will likely be limited by low head	✸	Use poly-liner or impermeable membrane to seal bottom	Clay or silty soils may require pretreatment
Infiltration	Minimum distance to water table of 2 feet	Maximum slope of 6% Trenches must have flat bottom	Generally not allowed	Infiltration rate > 0.5 inch/hr
Enhanced Swales	Generally feasible however slope <1% may lead to standing water in dry swales	Often infeasible if slopes are 4% or greater	✸	✸
Biofilters (Filter Strips & Grass Channels)	✸	✸	✸	✸
Modular Pavers/Porous Pavement	✸	Maximum slope of 5%	✸	Underdrain system required for C and D soils

✸ - These BMPs typically have no limiting factors or constraints for physiographic factors or soils.

Physiographic Factors

Three key factors to consider are low-relief, high-relief, and karst terrain. In local areas, low relief (very flat) areas and high relief (steep and hilly) areas are found throughout. Karst and major carbonaceous rock areas are found throughout portions of the local area. Special geotechnical testing requirements may be needed in karst areas. The local jurisdiction should be consulted to determine if a project is subject to terrain constraints.

- Low relief areas need special consideration because many structural BMPs require a hydraulic head to move stormwater runoff through the facility.
- High relief areas may limit use of some structural BMPs that need flat or gently sloping areas to settle out sediment or to reduce velocities. In other cases high relief may impact embankment heights to the point that a structural BMP becomes infeasible.
- Karst areas can limit the use of some structural BMPs as the infiltration of polluted waters directly into underground streams found in karst areas may be prohibited. In addition, ponding areas may not reliably hold water in karst areas.

Soils

The key evaluation factors are based on an initial investigation of the Natural Resources Conservation Service (NRCS) hydrologic soils groups at the site. Note that more detailed geotechnical tests are usually required for infiltration feasibility and during design to confirm permeability and other factors.

Additionally, the design of structural stormwater controls is fundamentally influenced by the nature of the downstream water body that will be receiving the stormwater discharge. In some cases, higher pollutant removal or environmental performance is needed to fully protect aquatic resources and/or human health and safety within a particular watershed or receiving water. Special design criteria for a particular structural control or the exclusion of one or more controls may need to be considered within these watersheds or areas. An important watershed factor to consider is the protection of drinking water sources, wellheads and surface reservoirs. Wellhead protection areas that recharge existing public water supply wells present a unique management challenge. The key design constraint is to prevent possible groundwater contamination by preventing infiltration of hotspot runoff. At the same time, recharge of unpolluted stormwater is encouraged to maintain flow in streams and wells during dry weather. Watersheds that deliver surface runoff to a public water supply reservoir or impoundment are a special concern also. Depending on the treatment available at the water intake, it may be necessary to achieve a greater level of pollutant removal for the pollutants of concern, such as bacteria pathogens, nutrients, sediment or metals. One particular management concern for reservoirs is ensuring that stormwater hotspots are adequately treated so that they do not contaminate drinking water.

Step 3: Location and Permitting Considerations

In the last step, a site designer assesses the physical and environmental features at the site to determine the optimal location for the selected structural BMP or group of BMPs. Table 4-6 provides a condensed summary of current restrictions as they relate to common site features that may be regulated under local, state or federal law. These restrictions fall into one of three general categories:

- Locating a structural BMP within an area that is expressly prohibited by law.
- Locating a structural BMP within an area that is strongly discouraged, and is only allowed on a case-by-case basis. Local, state and/or federal permits may be needed, and the applicant will need to supply additional documentation to justify locating the BMP within the regulated area.
- Locating a BMP based upon setbacks from a site feature or features.

This checklist is only intended as a general guide to location and permitting requirements as they relate to siting of stormwater structural BMPs. Developers and engineers are encouraged to consult the appropriate permitting agency if any of the site features listed in Table 4-6 are encountered on the development or redevelopment site.

Table 4-6. BMP Location and Permitting Checklist

Site Feature and Regulatory Agency	General Location and Permitting Guidance
Jurisdictional Wetlands (Waters of the U.S) U.S. Army Corps of Engineers Section 404 Permit Jurisdictional Engineering Dept.	• Jurisdictional wetlands should be delineated prior to sitting structural control. • Use of natural wetlands for stormwater quality treatment is contrary to the goals of the Clean Water Act and should be avoided. • Stormwater should be treated prior to discharge into a natural wetland. • Structural BMPs may also be restricted in buffer zones, although they may be utilized as a non-structural filter strip (i.e., accept sheet flow). • Justification must be provided that no practical upland treatment alternatives exist for wetland impacts by structural BMPs. • Where practical, excess stormwater flows should be conveyed away from jurisdictional wetlands.
Stream Channels (Waters of the U.S) U.S. Army Corps of Engineers Section 404 Permit TDEC Jurisdictional Engineering Dept. Tennessee Valley Authority	• All Waters of the U.S. (streams, basins, lakes, etc.) should be delineated prior to design. • Waters of the U.S. should not be used for stormwater quality treatment. In-stream basins for stormwater quality treatment are highly discouraged. • Stormwater should be treated prior to discharging into Waters of the U.S. • Justification must be provided that no practical upland treatment alternatives exist for stream impacts by structural BMPs. • Temporary runoff storage preferred over permanent pools. • Implement measures that reduce downstream warming.
Sinkholes TDEC Jurisdictional Engineering Dept.	• The local jurisdiction may require additional BMPs to prevent flooding or additional information to verify structural integrity.
Wellhead Protection Zones TDEC	• Infiltration BMPs may be prohibited due to proximity to wellhead protection zones for public water supplies. TDEC required setbacks for public water systems will be enforced.
100-Year Floodplains Jurisdictional Engineering Dept.	• Grading and fill for structural control construction is prohibited within the designated floodway as delineated by FEMA flood insurance rate maps, FEMA flood boundary and floodway maps, or as determined by the local jurisdiction.
Vegetated Buffers Jurisdictional Engineering Dept.	• Stormwater BMPs that will prevent a significant area of the buffer from reaching the vegetative target are prohibited.
Utilities Local utility district	• Call appropriate utility district to locate existing utilities prior to design. • Note the location of proposed utilities to serve development. • Structural BMPs are discouraged within utility easements or rights-of-way for public or private utilities.
Roads Jurisdictional Engineering Dept. TDOT	• Approval must also be obtained for any stormwater discharges to a local or state-owned conveyance channel.
Structures and Property Lines Local Jurisdiction	• Consult Chapter 4 of this manual for structural BMP setbacks from structures. • Recommended setbacks for each structural BMP are provided in the performance criteria in this manual.
Septic Drainfields Local Health Department	• Consult local Health Department.
Water Wells Local Health Department	• Consult local Health Department.

4.2.5 Limited Application BMP Screening Process

Outlined below is a screening process for limited application BMPs designed to assist the site designer and design engineer in the evaluation of the performance and applicability of the various limited application BMPs. Through the use of Table 4-7, the site designer can evaluate and screen the list of limited application structural BMPs to determine if a particular BMP or set of BMP(s) is appropriate.

As with the general application BMPs, the site designer assesses the physical and environmental features at the site to determine the optimal location for the selected BMP(s) or group of BMPs using Table 4-7 (Location and Permitting Checklist).

Evaluation Criteria

The following are the details of the various screening categories and individual characteristics used to evaluate the structural BMPs listed in Table 4-7.

Water Quality Treatment

% TSS Reduction. This column indicates the pollutant removal value assigned to each BMP type. If the BMP has a value of less than 80% TSS, then the BMP must be used in a treatment train with other BMPs to meet the overall weighted TSS reduction goal.

Site Applicability

The next two columns in Table 4-7 provide an overview of the specific site conditions or criteria that must be met for a particular limited application structural BMP to be suitable. Please see the specific criteria for each BMP provided in Section 4.3 for more details.

Drainage Area. This column indicates the approximate minimum or maximum drainage area that is considered suitable for the structural BMP.

Space Required (Space Consumed). This comparative index expresses how much space a structural BMP typically consumes at a site in terms of the approximate area required as a percentage of the impervious area draining to the control.

Implementation Considerations

The last group of columns in Table 4-7 provides additional considerations for the applicability of each structural BMP option.

Residential Subdivision. A check mark in this column identifies whether or not a structural control is suitable for typical residential subdivision development (not including high-density or ultra-urban areas).

High Density / Ultra-Urban. A check mark in this column identifies those structural controls that are appropriate for use in very high-density (ultra-urban) areas, or areas where space is a premium.

Capital Cost. The structural controls are ranked according to their relative construction cost per impervious acre treated as determined from cost surveys.

Maintenance Burden. This column assesses the relative maintenance effort needed for a structural stormwater control, in terms of three criteria: frequency of scheduled maintenance, chronic maintenance problems (such as clogging) and reported failure rates. It should be noted that all structural BMPs require routine inspection and maintenance.

Commercially Manufactured Systems Available? This column indicates if a structural control is available as a pre-manufactured commercial product from a vendor.

Table 4-7. Limited Application BMP Screening Matrix

STRUCTURAL BMP CATEGORY	STRUCTURAL BMP	WATER QUALITY	SITE APPLICABILITY		IMPLEMENTATION CONSIDERATIONS				
		% TSS Reduction	Drainage Area (acres)	Space Req'd (% of tributary imp. Area)	Residential Subdivision Use	High Density / Ultra-Urban	Capital Cost	Maintenance Burden	Commercially Manufactured Systems Available?
Filtering Practices	Organic Filter	80	10 max**	2-3%		✓	High	High	
	Underground Sand Filter	80	5 max	None		✓	High	High	Yes
Wetland Systems	Submerged Gravel Wetland	80	5 max**	2-3%		✓	High	High	
Porous Surfaces[1]	Porous Concrete	*	5 max	Varies		✓	Medium	High	
	Modular Porous Paver Systems	*	5 max	Varies	✓	✓	High	High	Yes
Chemical Treatment	Alum Treatment System	90	25 min	None	✓	✓	High	High	
Proprietary Systems	Commercial Stormwater Controls*	***	***	***	***	***	***	***	Yes
Separator Units	Oil/Grit Oil/Water Gravity	30	1 max	***		✓	Medium	High	Yes

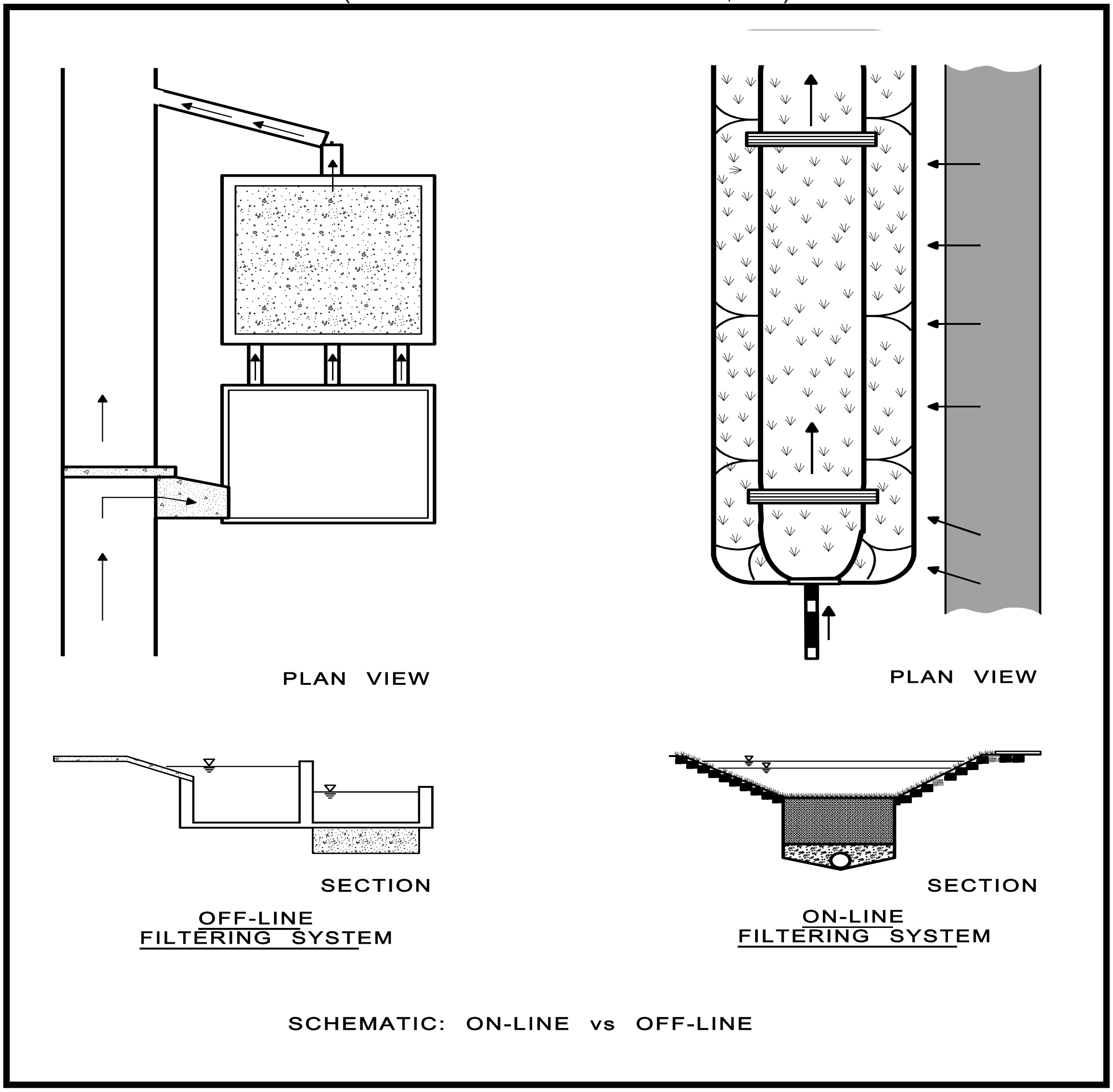
✓ Meets suitability criteria
* These practices are source controls and are not designed as pollutant removal devices.
** Drainage area can be larger in some instances
*** The application, performance and maintenance requirements of specific commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data
[1] Porous surfaces provide water quantity benefits by reducing the effective impervious area

4.2.6 Off-Line Versus On-Line Structural BMPs

Structural stormwater controls are designed either as “off-line” or “on-line” stormwater quality treatment controls. Examples of off-line and on-line BMPs are presented in Figure 4-1.

Off-line structural BMPs provide stormwater treatment (or other control) away from the flowpath of the runoff, and therefore, are typically designed only to receive a specified discharge rate (the water quality peak discharge) or volume. After the design runoff flow has been treated and/or controlled it is returned to the conveyance system. In contrast, on-line facilities, such as a stormwater treatment channel, typically provide stormwater control within the flowpath of the runoff. Because of this, on-line facilities often must be able to handle the entire range of design storm discharges, up to the locally regulated storm event. Techniques and calculation methods for proper sizing of off-line BMPs are presented in Chapter 3 of this manual.

Figure 4-1. Example of Off-Line versus On-Line Structural Controls
(Source: Center for Watershed Protection, 1996)



A flow regulator (e.g., diversion structure, flow splitter, etc.) is used to direct stormwater to off-line structural BMPs. Examples of flow regulators are shown in Figures 4-2 through 4-4 below.

Figure 4-2. Pipe Interceptor Diversion Structure
(Source: City of Sacramento, 2000)

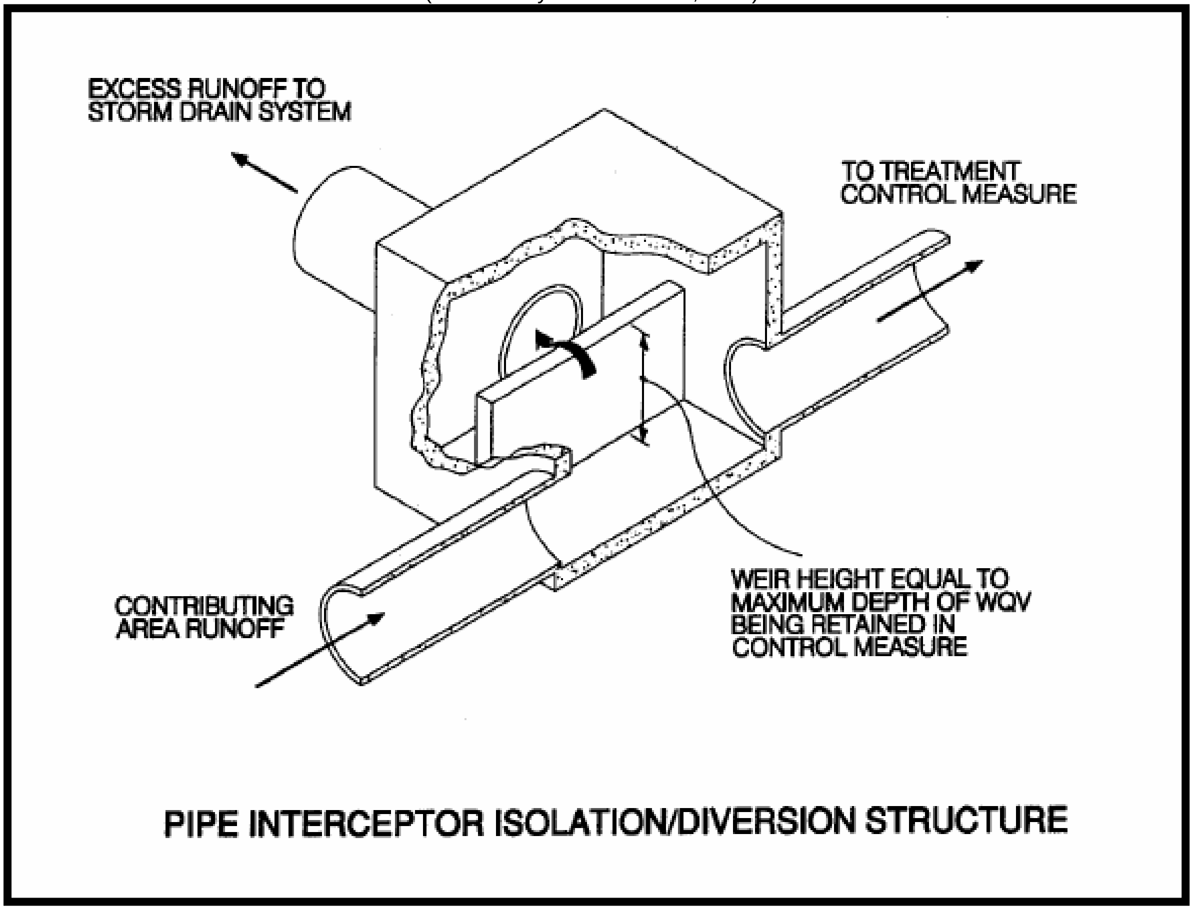


Figure 4-3. Regulator
(Source: City of Sacramento, 2000)

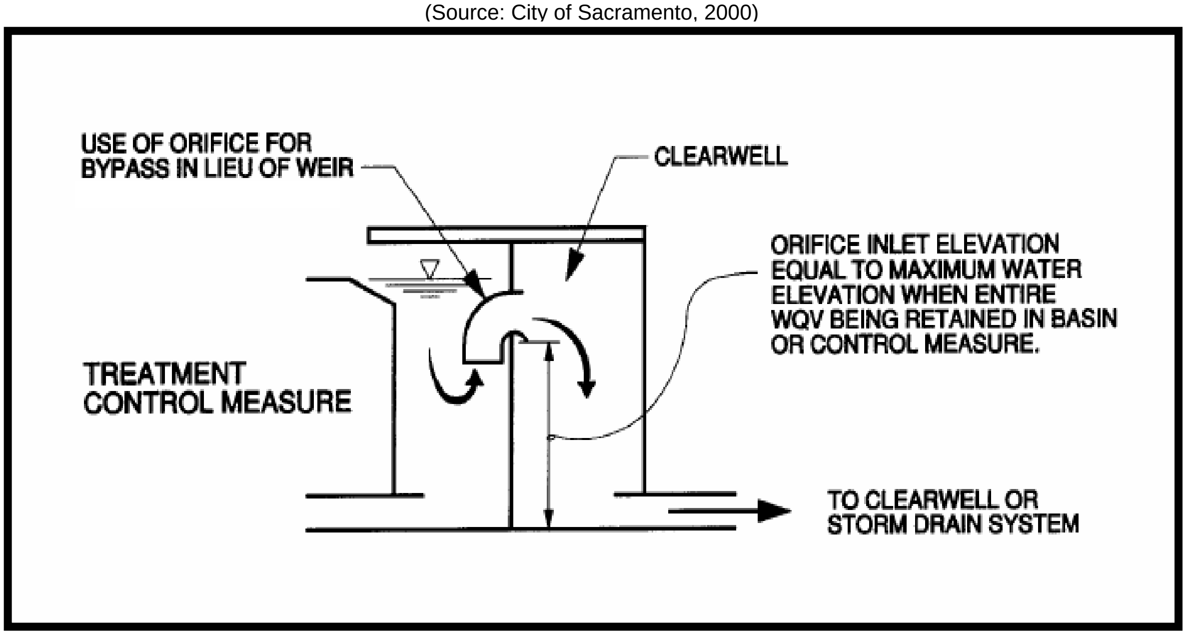
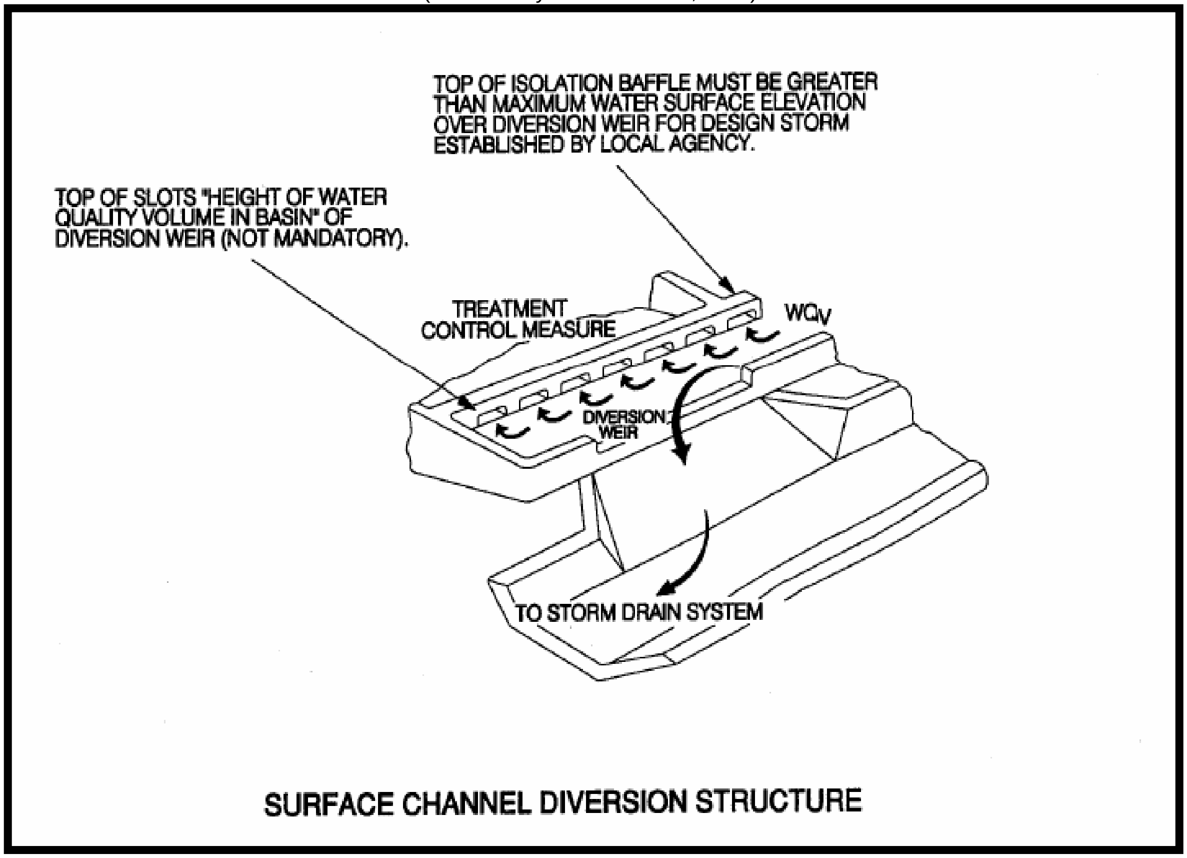


Figure 4-4. Surface Channel Diversion Structure
(Source: City of Sacramento, 2000)



4.2.7 Using Structural Stormwater BMPs in Series

The minimum stormwater management standards are an integrated planning and design approach whose components work together to limit the adverse impacts of urban development on downstream waters and riparian areas. This approach is sometimes called a stormwater "treatment train", where two or more structural (and sometimes non-structural) BMPs work in series to treat and control stormwater runoff. The calculation of % TSS removal for BMPs in series is discussed in detail in Chapter 3.

When considered comprehensively, a treatment train consists of all the design concepts and nonstructural and structural BMPs that work to attain water quality and quantity goals. This is illustrated in Figure 4-5, and is described below.

Figure 4-5. Generalized Stormwater Treatment Train

Runoff and Load Generation – The initial part of the "train" is located at the source of runoff and pollutant load generation, and consists of better site design and pollution prevention practices that reduce runoff and stormwater pollutants.

Pretreatment – The next step in the treatment train consists of pretreatment measures. These measures typically do not provide sufficient pollutant removal to meet the 80% TSS reduction goal, but do provide calculable water quality benefits that may be applied towards meeting the WQv treatment requirement. These measures include:

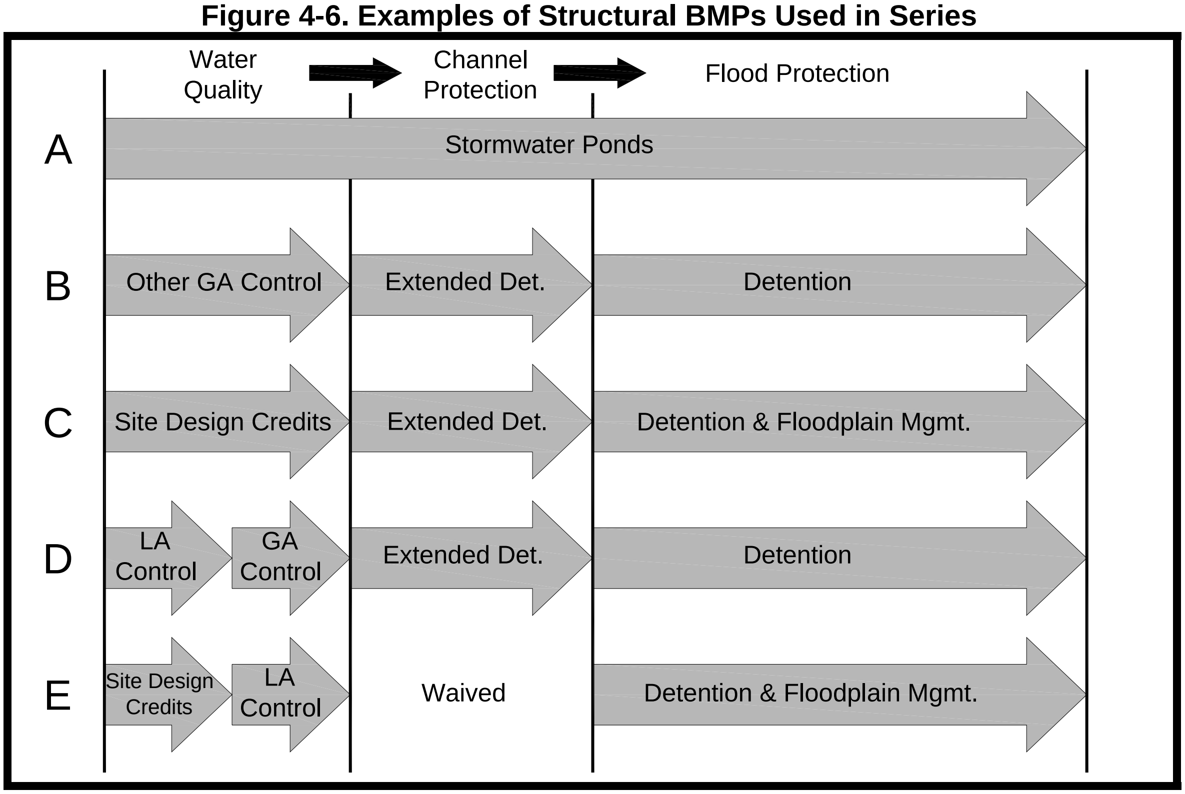
- The use of stormwater better site design practices and reductions to reduce the generation of stormwater runoff and thereby reducing the WQv;
- Limited application BMPs that provide pretreatment; and
- Pretreatment facilities such as sediment forebays on General Application BMPs.

Primary Treatment and/or Quantity Control – The last step is primary water quality treatment and/or quantity (channel protection, overbank flood protection, and/or extreme flood protection) control. This is achieved through the use of general or limited application BMPs, or detention facilities. It should be noted that controls installed to reduce the runoff load and to provide pretreatment can affect the size of the primary treatment control.

4.2.7.1 Use of Multiple Structural BMPs in Series

Many combinations of structural BMPs in series may exist for a site. Figure 4-6 provides a number of hypothetical examples of structural BMPs, that when used in a treatment train, can satisfy the stormwater design criteria for water quality treatment, channel protection, overbank flooding and extreme flooding. In Figure 4-6, GA indicates General Application BMPs, LA indicates Limited Application BMPs.

Figure 4-6. Examples of Structural BMPs Used in Series



Referring to Figure 4-6 by line letter:

A. One general application BMP, stormwater basins, can be used as a stand-alone to meet all the design criteria.

B. Other general application (GA) BMPs (bioretention, sand filters, infiltration trench and enhanced swale) are typically used in combination with detention controls to meet the WQv, CPv, and the locally regulated storm event criteria. The detention facilities are located downstream from the water quality controls either on-site or combined into a regional or neighborhood facility.

C. Line C indicates the condition where an environmentally sensitive large lot neighborhood (discussed in Chapter 5) has been developed that can be designed so as to waive the water quality treatment requirement altogether. However, detention controls may still be required for downstream channel protection and locally regulated peak flow control.

D. Where a limited application (LA) structural BMP does not meet the 80% TSS removal criteria, another downstream structural control must be added. For example, an urban hotspot land use may be fit or retrofit with devices adjacent to parking or service areas designed to remove oil and grease and may also serve as pretreatment devices removing the coarser fraction of sediment. One or more downstream structural controls is then used to meet the full 80% TSS removal goal, and well as water quantity control.

E. In Line E site design reductions have been employed to partially reduce the water quality volume requirement. In this case, for a smaller site, a well designed and tested Limited Application structural control provides adequate TSS removal while a dry detention basin handles the locally regulated flooding criteria. For this location, direct discharge to a large stream and local downstream floodplain management practices have eliminated the need for channel protection volume.

The combinations of structural stormwater BMPs are limited only by the need to employ measures of proven effectiveness and meet local regulatory and physical site requirements. Figures 4-7, 4-8 and 4-9, illustrate the application of the treatment train concept for: a moderate density residential neighborhood, a small commercial site, and a large shopping mall site, respectively.

In Figure 4-7 rooftop runoff drains over grassed yards to backyard grass channels. Runoff from front yards and driveways reaches roadside grass channels. Finally, all stormwater flows to a micropool ED stormwater basin.

A gas station and convenience store is depicted in Figure 4-8. In this case, the decision was made to intercept hydrocarbons and oils using a commercial gravity (oil-grit) separator located on the site prior to draining to a perimeter sand filter for removal of finer particles and TSS. Flood protection is provided by a regional stormwater control downstream.

Figure 4-9 shows an example treatment train for a commercial shopping center. In this case, runoff from rooftops and parking lots drains to a depressed parking lot, perimeter grass channels, and bioretention areas. Slotted curbs are used at the entrances to these swales to better distribute the flow and to settle out the very coarse particles at the parking lot edge for sweepers to remove. Runoff is then conveyed to a wet ED basin for additional pollutant removal and channel protection. Flood protection is provided through parking lot detention.

Figure 4-7. Example Treatment Train – Residential Subdivision
(Adapted from: Atlanta Regional Council, 2001)

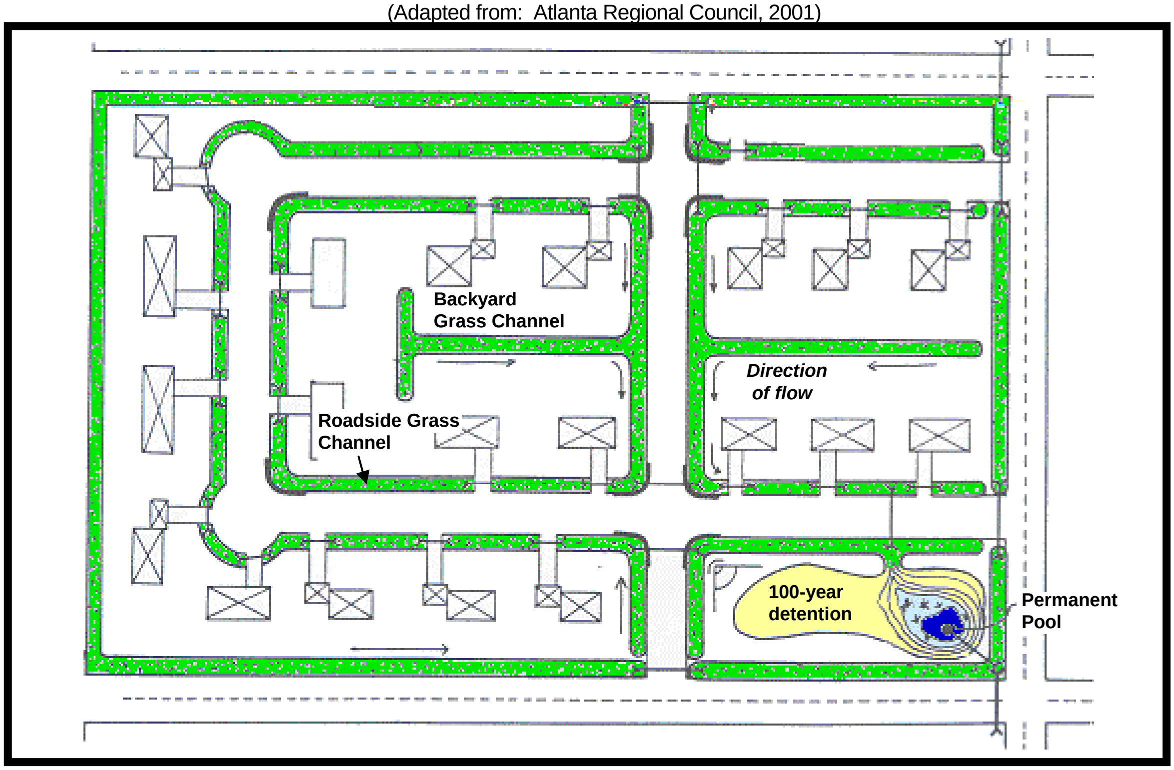


Figure 4-8. Example Treatment Train – Commercial Development #1

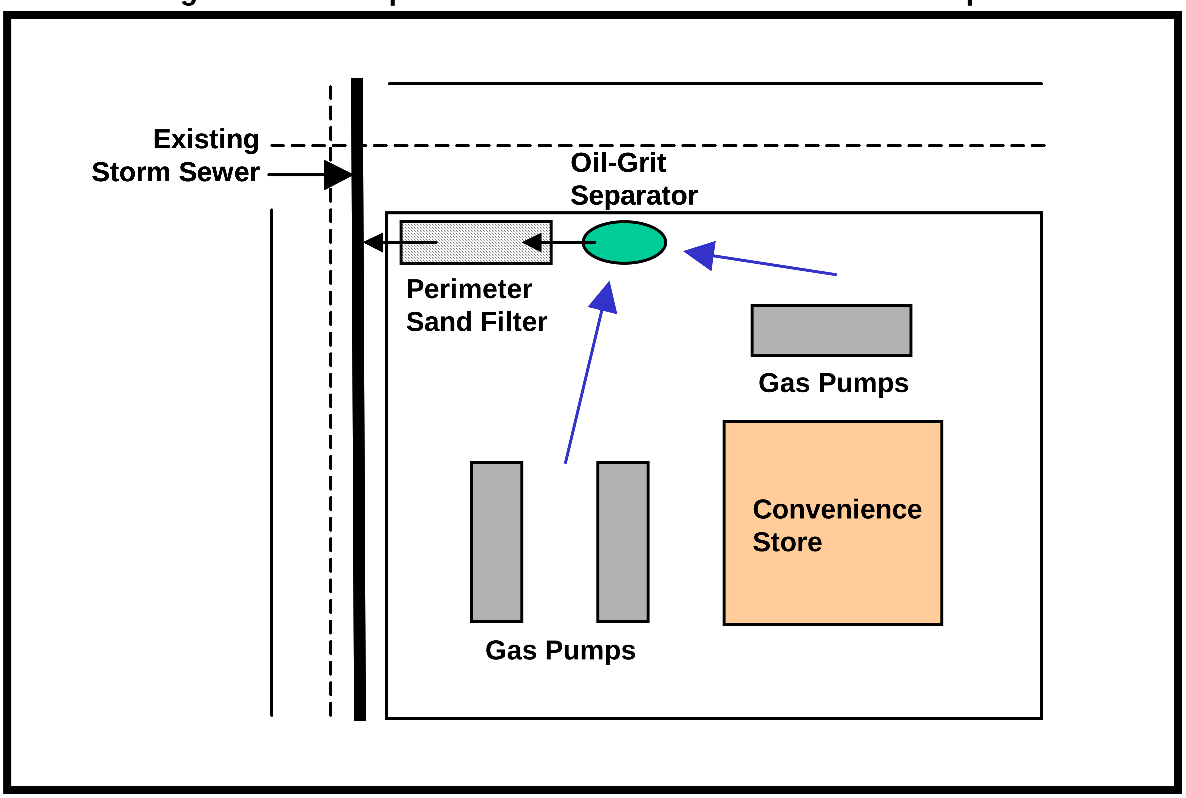
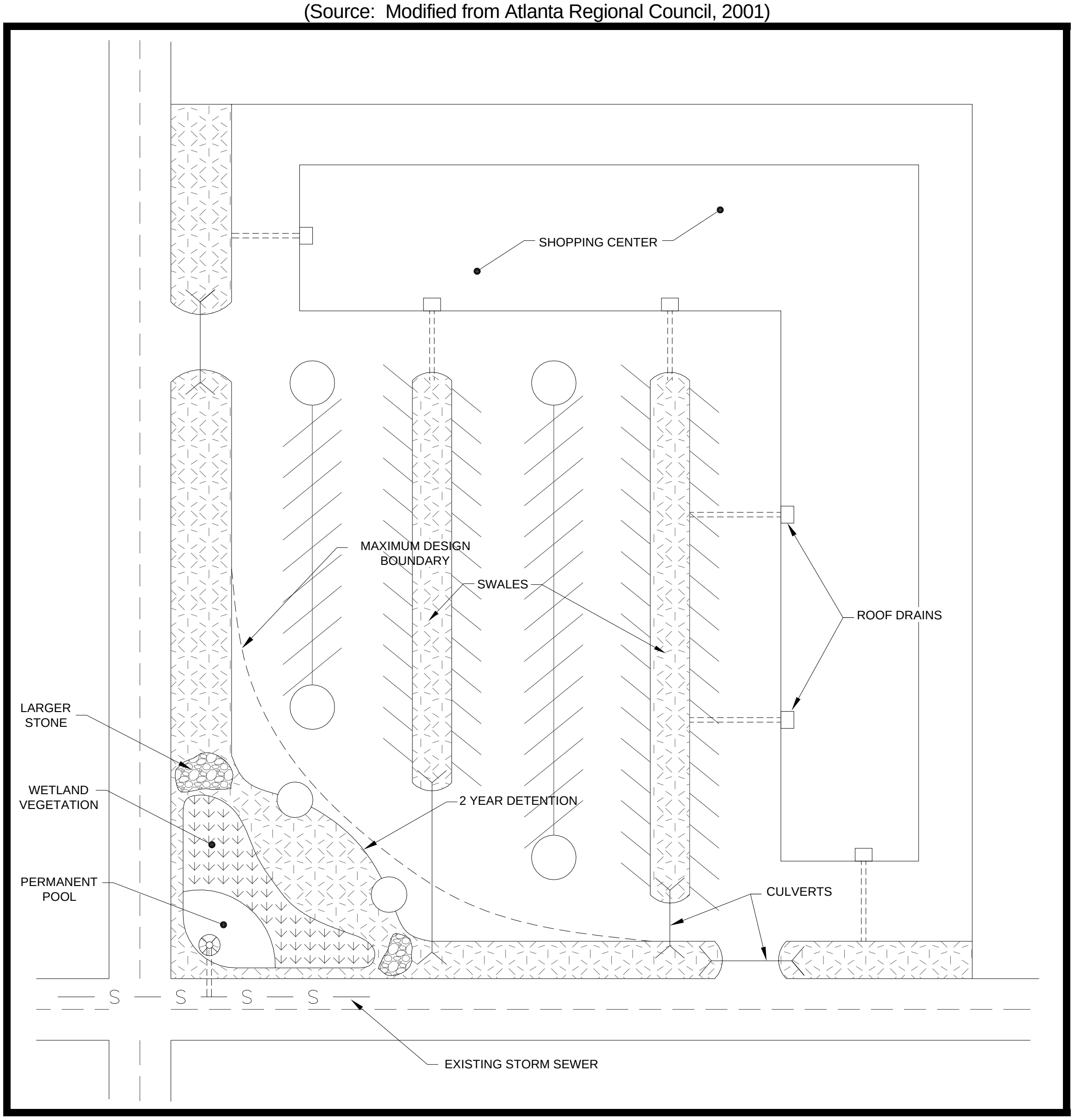


Figure 4-9. Example Treatment Train – Commercial Development #2
(Source: Modified from Atlanta Regional Council, 2001)



4.2.8 References

City of Nashville, Tennessee. *Metropolitan Nashville and Davidson County Stormwater Management Manual, Volume 4 Best Management Practices.* 2006.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

Center for Watershed Protection. *Design of Stormwater Filtering Systems*. Prepared for the Chesapeake Research Consortium 1996.

City of Sacramento Department of Utilities. *Guidance Manual for On-Site Stormwater Quality Control Measures*. 2000.

This page left intentionally blank

4.3.1 Water Quality Basins

General Application
Water Quality BMP

Description: A constructed water quality basin that has a permanent pool (or micropool). Runoff from each rain event is detained and treated in the pool primarily through settling and biological uptake mechanisms.

KEY CONSIDERATIONS

FEASIBILITY GUIDELINES:

- Minimum contributing drainage area of 25 acres; 10 acres for micropool ED basin.
- Requires approximately 2 to 3% of the contributing drainage area.
- Underlying soils of hydrologic groups C or D are typically adequate to maintain a permanent pool. Hydrologic soil groups A and B, or areas with karst topography require a basin liner.
- Shall not be located on unstable slopes or slopes greater than 15%.
- Six to eight feet of elevation difference is needed from inflow to outflow.
- There are additional design requirements for areas with underlying aquifers or hotspot areas.

ADVANTAGES / BENEFITS:

- Moderate to high removal rate of urban pollutants.
- High community acceptance if aesthetics are maintained.
- Opportunity for wildlife habitat.

DISADVANTAGES / LIMITATIONS:

- Potential for thermal impacts/downstream warming.
- Dam height restrictions for high relief areas.
- Basin drainage can be problematic for low relief terrain.

MAINTENANCE REQUIREMENTS:

- Remove debris from inlet and outlet structures.
- Maintain side slopes / remove invasive vegetation.
- Monitor sediment accumulation and remove periodically.

STORMWATER MANAGEMENT APPLICABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**Yes**
Detention/Retention:	**Yes**

Accepts hotspot runoff: *Yes, but two feet of separation distance required to water table when used in hotspot areas*

COST CONSIDERATIONS

Land Requirement:	**Med - High**
Capital Cost:	**Low**
Maintenance Burden:	**Low**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**80%**

4.3.1.1 General Description

Water quality basins (also referred to as retention basins, wet basins, or wet extended detention basins) are constructed stormwater retention basins that have a permanent (dead storage) pool of water throughout the year. They can be created by excavating an already existing natural depression or through the construction of embankments.

In a water quality basin, runoff from each rain event is detained and the water quality volume (WQv) is treated in the pool through gravitational settling and biological uptake until it is displaced by runoff from the next storm. The permanent pool also serves to protect deposited sediments from resuspension. Above the permanent pool level, additional temporary storage (live storage) is provided for runoff quantity (i.e., peak discharge and/or volume) control if required by local regulations. The upper stages of a water quality basin can be designed to provide extended detention for downstream channel protection volume, as well as conventional detention for peak discharge control.

Water quality basins are among the most cost-effective and widely used stormwater practices. Water quality basins are generally applicable to most types of new development and redevelopment, and can be used in both residential and nonresidential areas. Basins can also be used for regional applications (i.e., controlling runoff from more than one developed site). A well-designed and landscaped basin can be an aesthetic feature on a development site when planned and located properly. However, limitations on available land may preclude their use for retrofit applications or high-density/ultra urban sites.

There are several variations of water quality basin design, the most common of which include the wet basin, the wet extended detention basin, and the micropool extended detention basin. In addition, multiple water quality basins can be placed in series or parallel to increase total suspended solids (TSS) removal efficiency or meet site design constraints. Figure 4-10 shows a number of examples of water quality basins. Descriptions of each basin type are provided below the figure.

Figure 4-10. Water Quality Basin Examples

Wet Basin

Wet Extended Detention Basin

Micropool Extended Detention Basin

Multiple Basin System

- **Wet Basin** – Wet basins are water quality basins constructed with a permanent (dead storage) pool of water equal to the WQv. Stormwater runoff displaces the water already present in the pool. Temporary storage (live storage) can be provided above the permanent pool elevation for larger flows.

- **Wet Extended Detention (ED) Basin** – A wet extended detention basin is a wet basin where the WQv is split evenly between the permanent pool and extended detention (ED) storage provided above the permanent pool. During storm events, water is detained above the permanent pool and released over 24 hours. This design has similar pollutant removal to a traditional wet basin, but consumes less space.
- **Micropool Extended Detention (ED) Basin** – The micropool extended detention basin is a variation of the wet ED basin where only a small "micropool" is maintained at the outlet to the basin. The outlet structure is sized to detain the WQv for 24 hours. The micropool prevents resuspension of previously settled sediments and also prevents clogging of the low flow orifice.
- **Multiple Basin System** – A multiple basin system consists of constructed facilities that provide water quality and quantity volume storage in two or more cells. The additional cells can create longer pollutant removal pathways and improved downstream protection.

4.3.1.2 Pollutant Removal Capabilities

Basins treat incoming stormwater runoff through physical, biological, and chemical processes. The primary removal mechanism is gravitational settling of particulates, organic matter, metals, bacteria and organics as stormwater runoff resides in the basin. Another mechanism for pollutant removal is uptake by algae and wetland plants in the permanent pool, particularly of nutrients. Volatilization and chemical activity also work to break down and eliminate a number of other stormwater contaminants such as hydrocarbons.

All of the water quality basin design variations are presumed capable of removing at least 80% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the specifications provided in this manual. The TSS removal performance can be reduced by poor design, construction or maintenance.

Additionally, research has shown that use of water quality basins will have benefits beyond the removal of TSS, such as the removal of other pollutants (i.e. phosphorous, nitrogen, fecal coliform and heavy metals) as well, which is useful information should the pollutant removal criteria change in the future.

For additional information and data on pollutant removal capabilities for water quality basins, see the National Pollutant Removal Performance Database (2nd Edition) available at www.stormwatercenter.net and the International Stormwater Best Management Practices Database at www.bmpdatabase.org.

4.3.1.3 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of a water quality basin facility. Water quality basins that are not designed to these standards will not be approved. Consult with the local engineering department to determine if there are any variations to these criteria or additional standards that must be followed.

A. LOCATION AND SITING

- Water quality basins must have a minimum contributing drainage area of 25 acres or more for a wet basin or wet ED basin to maintain a permanent pool. For a micropool ED basin, the minimum drainage area is 10 acres. The use of a water quality basin for a smaller drainage area may be considered when water availability can be confirmed (such as from a groundwater source or areas that typically have a high water table). In such situations, calculation of a water balance for the basin may be required. Water balance calculations are presented in Chapter 3 of this manual. It is important that basins that serve smaller drainage areas have an adequate anti-clogging device provided for the basin outlet.
- It is strongly recommended that water quality basins be located where the topography allows for maximum runoff storage at minimum excavation or embankment construction costs. When locating a water quality basin, the site designers should also consider the location and use of other site features,

such as buffers and undisturbed natural areas, and should attempt to aesthetically blend the facility into the adjacent landscape.

- Water quality basins shall not be located on unstable slopes or slopes greater than 15%.
- Water quality basins shall not be located in a stream or any other navigable waters of the United States, including natural (i.e., not constructed) wetlands. Where an appeal or variance of this policy is desired, the property owner must obtain coverage under a Section 404 permit under the Clean Water Act and/or an Aquatic Resource Alteration Permit (ARAP) and provide proof of such coverage with the site development plans on which the basin design is presented.
- Each water quality basin shall be placed in an easement that is recorded with the deed. The easement shall be defined at the outer edge of the safety bench, or a minimum of 15 feet from the normal water pool elevation (measured perpendicular from the pool elevation boundary) if a safety bench is not included in the basin design. Minimum setback requirements for the easement shall be as follows unless otherwise specified by local regulations:
    - From a public water system well – TDEC specified distance per designated well category
    - From a private well – 50 feet; if the well is down gradient from a hotspot land use, as defined in this manual, then the minimum setback is 250 feet
    - From a septic system tank/leach field – 50 feet
- The minimum setback for habitable structures from the easement shall be 15 feet. The first floor elevation (FFE) for any structure adjacent to the basin shall have an elevation no lower than 1 foot above the top of the berm.
- All utilities shall be located outside of the easement.

B. GENERAL DESIGN

- A water quality basin shall consist of the following elements, designed in accordance with the specifications provided in this section.
    (1) Permanent pool of water;
    (2) A sediment forebay at each basin inlet (unless the inlet provides less than 10% of the total inflow to the basin);
    (3) Overlying zone in which runoff control volumes are stored;
    (4) Shallow littoral zone (aquatic bench) along the edge of the permanent pool that acts as a biological filter;
    (5) An emergency spillway;
    (6) Maintenance access;
    (7) Safety bench (if basin side slopes are greater than 3:1); and,
    (8) Appropriate native landscaping.

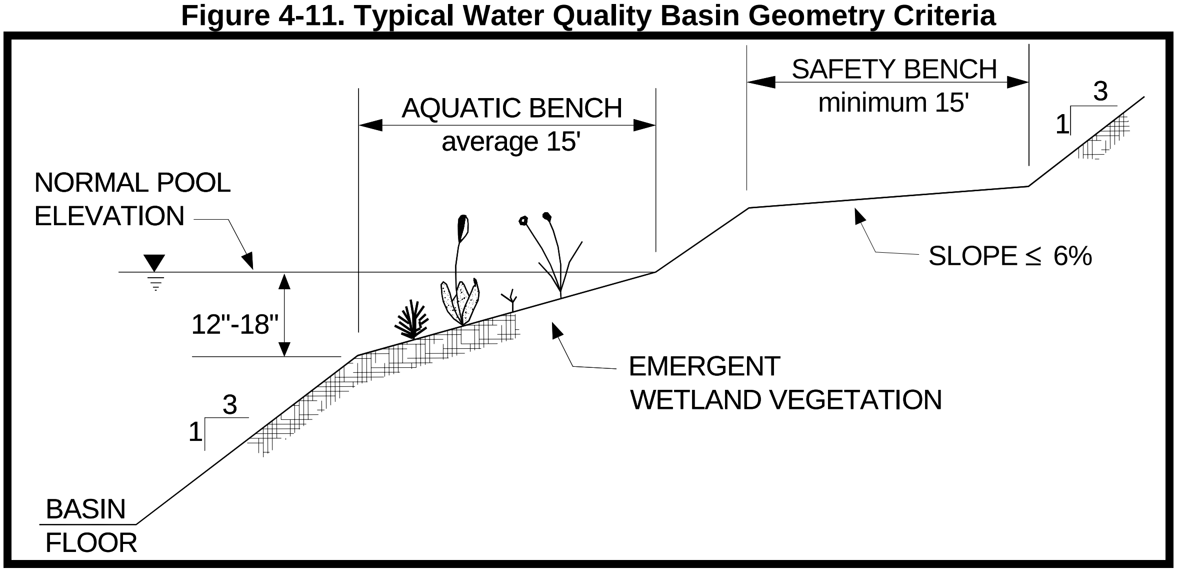
C. PHYSICAL SPECIFICATIONS / GEOMETRY

In general, basin designs are unique for each site and application. However, there are a number of geometric ratios and limiting depths for basin design that must be observed for adequate pollutant removal, ease of maintenance, and improved safety.

- Permanent pool volume shall be sized as follows:
    - Standard wet basins: 100% of the water quality treatment volume (1.0 X WQv);
    - Wet ED basins: 50% of the water quality treatment volume (0.5 X WQv);
    - Micropool ED basins: Approximately 0.1 foot per impervious acre (4356 ft^3).

- The pretreatment storage volume is part of the total WQv design requirement and may be subtracted from the WQv for permanent pool sizing. See Part D below for more information.
- Proper geometric design is essential to prevent hydraulic short-circuiting (unequal distribution of inflow), which results in the failure of the basin to achieve adequate levels of pollutant removal. The minimum length-to-width ratio permitted for the permanent pool shape is 1.5:1, and should ideally be greater than 3:1 to avoid short-circuiting. In addition, basins should be wedge-shaped when possible so that flow enters the basin and gradually spreads out, improving the sedimentation process. Baffles, basin shaping or islands can be added within the permanent pool to increase the flow path.
- The maximum depth of the permanent pool shall not exceed 8 feet to avoid stratification and anoxic conditions. Greater depths may be approved in the event that measures are taken that will eliminate the possibility of such conditions and safety precautions are adequately considered. The minimum depth for the permanent pool should be 3 to 4 feet. Deeper depths near the outlet will result in cooler bottom water discharges from the basin, which may mitigate downstream thermal effects caused by discharges of warm stormwater runoff.
- Side slopes shall not exceed 3:1 (horizontal to vertical) on one side of the basin to facilitate access for maintenance and repair. The remainder of the basin shall have side slopes no steeper than 2:1 although 3:1 is preferred. Benching of the slope (see safety bench in Figure 4-11) is required for embankments greater than 10 feet in height and having greater than a 3:1 side slope. Riprap-protected embankments shall be no steeper than 2:1.
- The perimeter of all deep pool areas (4 feet or greater in depth) shall be surrounded by two benches: safety and aquatic. For large basins, the safety bench shall extend no less than 15 feet outward from the normal water edge to the toe of the basin side slope. The slope of the safety bench shall not exceed 6%. The requirements for a safety bench may be waived if basin side slopes are 3:1 or gentler. The aquatic bench shall have an average width of 15 feet, and shall extend inward from the normal pool edge and shall have a maximum depth of 18 inches below the normal pool water surface elevation (see Figure 4-11).
- The contours and shape of the permanent pool should be irregular to provide a more natural landscaping effect.

Figure 4-11. Typical Water Quality Basin Geometry Criteria



D. PRETREATMENT / INLETS

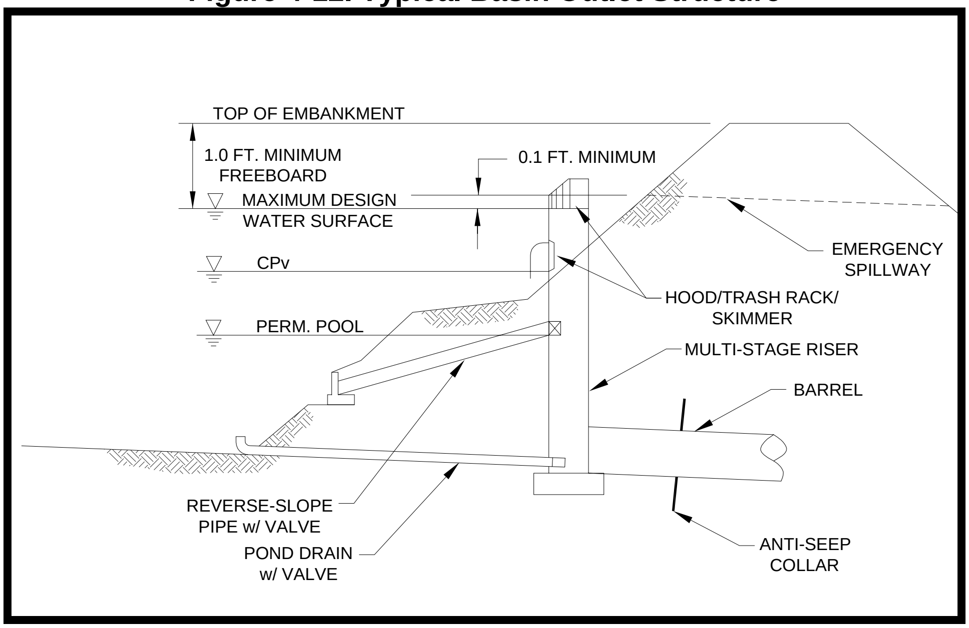
- Each basin shall have a sediment forebay or equivalent upstream pretreatment. A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to dispersal in a larger permanent pool. The forebay shall consist of a separate cell, formed by an acceptable barrier. A forebay must be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the basin. In some design configurations, the pretreatment volume may be located within the permanent pool.

- The sediment forebay shall be sized to contain 0.1 inch per impervious acre (363 ft^3) of contributing drainage and shall be no more than 4 to 6 feet deep. The pretreatment storage volume is part of the total WQv design requirement and may be subtracted from the WQv for permanent pool sizing.
- A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.
- Inflow channels shall be stabilized with flared riprap aprons, or the equivalent. Inlet pipes to the basin can be partially submerged. Exit velocities of discharges from the forebay to the basin must be non-erosive.

E. OUTLET STRUCTURES

- Flow control from a water quality basin is typically accomplished with the use of a riser and barrel. The riser is a vertical pipe or inlet structure that is attached to the base of the basin with a watertight connection. The outlet barrel is a horizontal pipe attached to the riser that conveys flow under the embankment (see Figure 4-12). The riser shall be located within the basin embankment for maintenance access, safety and aesthetics.

Figure 4-12. Typical Basin Outlet Structure



- A number of outlets at varying depths in the riser provide internal flow control for routing of the WQv and CPv, and for peak discharge control (i.e., detention). The number of orifices can vary and is usually a function of the basin design.

  For example, a wet basin riser configuration is typically comprised of a channel protection (CPv) outlet (usually an orifice) and one or more outlets (often slots or weirs) for peak discharge control to comply with local detention requirements (e.g., control of the post-development 10-year peak discharge to pre-development conditions). The channel protection orifice is sized to release the channel protection storage volume over a 24-hour period, centroid to centroid. Since the water quality volume is fully contained in the permanent pool, no orifice sizing is necessary for this volume. As runoff from a water quality event enters the wet basin, it simply displaces that same volume through the channel protection orifice. Thus an off-line wet basin providing ***only*** water quality treatment can use a simple overflow weir as the outlet structure.

In the case of a wet ED basin or micropool ED basin, there is generally a need for an additional outlet (usually an orifice) that is sized to pass the extended detention water quality volume that is surcharged on top of the permanent pool. Flow will first pass through this orifice, which is sized to release the water quality ED volume in 24 hours. The preferred design is a reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool to prevent floatables from clogging the pipe and to avoid discharging warmer water at the surface of the basin. The next outlet is sized for the release of the channel protection storage volume. The outlet (often an orifice) invert is located at the maximum elevation associated with the extended detention water quality volume and is sized to release the channel protection storage volume over a 24-hour period. The final orifice invert is located at the extreme flood elevation.

Alternative hydraulic control methods to an orifice can be used and include the use of a broad-crested, rectangular, V-notch, or proportional weir, or an outlet pipe protected by a hood that extends at least 12 inches below the normal pool.

- Higher flows that must be controlled as part of the local jurisdiction's detention requirements pass through openings or slots protected by trash racks further up on the riser.
- After entering the riser, flow is conveyed through the barrel and is discharged downstream. Anti-seep collars shall be installed on the outlet barrel to reduce the potential for pipe or embankment failure.
- Riprap, plunge pads or pools, or other energy dissipators shall be placed at the outlet of the barrel to prevent scouring and erosion. If a basin outlet discharges immediately to a channel that carries dry weather flow (i.e., a stream), care shall be taken to minimize disturbance along the downstream channel, and to reestablish streamside vegetation in the shortest possible distance.
- Each basin shall have a bottom drain pipe with an adjustable slide gate that can completely or partially drain the basin within 24 hours.
- The basin drain shall be sized one pipe size greater than the calculated design diameter. The drain valve is typically a slide gate. Valve controls shall be located inside of the riser at a point where they: (a) will not normally be inundated; and (b) can be operated in a safe manner.
- Consult your local jurisdiction for materials specification for the outlet structure.

F. EMERGENCY SPILLWAY

- An emergency spillway shall be included per regulations of the local jurisdiction.

G. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right-of-way or easement shall be provided to the basin from a driveway, public road or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.
- The maintenance access shall extend to the forebay, safety bench, riser, and outlet, and, to the extent feasible, be designed to allow vehicles to turn around.
- Access to the riser shall be provided by lockable manhole covers, and manhole steps within easy reach of valves and other controls.

H. SAFETY FEATURES

- A safety bench shall be provided for embankments greater than 10 feet in height and having greater than a 3:1 side slope. For large basins, the safety bench shall extend no less than 15 feet outward from the normal water edge to the toe of the basin side slope. The slope of the safety bench shall not exceed 6%.
- All embankments and spillways shall be designed to TDEC rules and regulations as applied to the Safe Dams Act of 1973 (see Appendix H), where applicable.

- The property owner may consider fencing the basin for the purpose of safety management.
- All outlet structures shall be designed so as not to permit access by children. Property owners are encouraged to post warning signs near the basin to prohibit swimming and fishing in the facility.

I. LANDSCAPING

- Aquatic vegetation can play an important role in pollutant removal in a water quality basin. In addition, vegetation can enhance the appearance of the basin, stabilize side slopes, serve as wildlife habitat, and can temporarily conceal unsightly trash and debris. Therefore, wetland plants should be encouraged in a basin design, along the aquatic bench (fringe wetlands), the safety bench and side slopes (ED basins), and within shallow areas of the pool itself. The best elevations for establishing wetland plants, either through transplantation or volunteer colonization, are within 6 inches (plus or minus) of the normal pool elevation. More information on wetland plants can be found at the following websites:
  - http://wetlands.fws.gov/
  - http://www.npwrc.usgs.gov/resource/plants/floraso/species.htm
- Woody vegetation shall not be planted on the embankment or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.
- Fish such as *Gambusia* can be stocked in a basin to aid in mosquito prevention.
- A fountain or aerator may be used for oxygenation of water in the permanent pool and to aid in mosquito breeding prevention.
- Vegetated buffers, as defined and described in Chapter 6 of this manual, are not required for water quality basins that are constructed for the purpose of stormwater quality or quantity control. However, it should be noted that vegetated buffers can be utilized for water quality treatment and can result in a volume reduction that decreased the WQv. The criteria for the vegetated buffer reduction are presented in Chapter 5 of this manual.

J. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

There are a number of additional site specific design criteria and issues (listed below) that must be considered in the design of a water quality basin.

Physiographic Factors - Local terrain design constraints:

- Low Relief – Maximum normal pool depth is limited; providing the basin drain can be problematic.
- Karst – Requires poly or clay liner to sustain a permanent pool of water and protect aquifers; limits on ponding depth; geotechnical tests may be required.
- Soils - Hydrologic group “A” soils generally require a basin liner; group “B” soils may require infiltration testing.

Wellhead Protection Areas

- Reduce potential groundwater contamination in wellhead protection areas by preventing infiltration of runoff from hotspot areas, or provide pretreatment of this runoff for the target pollutants that may discharge from the land use.
- Wellhead protection may require liner for type “A” and “B” soils.
- A minimum of two (2) to four (4) feet separation distance of the basin from water table shall be provided.

4.3.1.4 Design Procedures

In general, site designers should perform the following design procedures when designing a water quality basin.

Step 1. Compute runoff control volumes

Calculate WQv CPv, and pre- and post-development peak discharges and runoff volumes. The calculation of WQv and CPv is presented in Chapter 3 of this manual. Consult local regulations for peak discharge control (i.e., detention) requirements.

Step 2. Determine if the development site and conditions are appropriate for a water quality basin

Consider the planning and design standards in sections 4.3.1.3.

Step 3. Confirm additional design criteria and applicability

Consider any special site-specific design conditions/criteria from subsection 4.3.1.3-J. Check with the local engineering department, TDEC, or other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply to the site.

Step 4. Determine pretreatment volume

A sediment forebay is provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the basin. The forebay should be sized to contain 0.1 inch per impervious acre (363 ft^3) of contributing drainage and should be 4 to 6 feet deep. The forebay storage volume counts toward the total WQv requirement and may be subtracted from the WQv for subsequent calculations.

Step 5. Determine permanent pool volume (and water quality ED volume)

Wet Basin: Size permanent pool volume to 1.0 WQv less any forebay storage volume.

Wet ED Basin: Size permanent pool volume to 0.5 WQv less any forebay storage volume. Size extended detention volume to 0.5 WQv less any forebay storage volume.

Micropool ED Basin: Size permanent pool volume at 0.1 foot per impervious acre (4356 ft^3) less any forebay storage volume. Size extended detention volume to remainder of WQv.

Step 6. Determine basin location and preliminary geometry. Conduct basin grading design and determine storage available for permanent pool (and water quality extended detention if needed)

This step involves initially designing the grading of the basin (establishing contours) and determining the elevation-storage relationship for the basin. See subsection 4.3.1.3 for more details.

- Include safety and aquatic benches, if required.
- Set WQv permanent pool elevation (and WQv-ED elevation for wet ED and micropool ED basin) based on volumes calculated earlier.

Step 7. Compute extended detention orifice release rate(s) and size(s), and establish CPv elevation

Wet Basin: The CPv elevation is determined from the stage-storage relationship and the orifice is then sized to release the channel protection storage volume over a 24-hour period. The channel protection orifice should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool, is a recommended design. Orifice diameters less than three inches must employ internal orifice protection (i.e., an over-perforated vertical stand pipe with ½-inch orifices or slots that are protected by wirecloth and a stone filtering jacket).

Wet ED Basin and Micropool ED Basin: Based on the elevations established in Step 6 for the extended detention portion of the water quality volume, the water quality orifice is sized to release this extended detention volume in 24 hours. The water quality orifice should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool, is a recommended design. Orifice diameters less than three inches must employ internal orifice protection (i.e., an over-perforated vertical stand pipe with ½-inch orifices or slots that are protected by wirecloth and a stone filtering jacket). The CPv elevation is then determined from the stage-storage relationship. The invert of the channel protection orifice is located at the water quality extended detention elevation, and the orifice is sized to release the channel protection storage volume over a 24-hour period, centroid to centroid.

<u>Step 8. Calculate peak discharge release rates and water surface elevations for flood control (i.e., detention)</u>

Set up a stage-storage-discharge relationship for the control structure for the extended detention (CPv) requirement and peak discharge control storm orifices.

<u>Step 9. Design embankment(s) and spillway(s)</u>

Using the peak event water surface elevation, set the top of the embankment elevation, and size the emergency spillway per the regulations of the local jurisdiction.

<u>Step 10. Investigate potential basin hazard classification</u>

The design and construction of water quality management basins are required to follow the latest version of the TDEC Rules and Regulations Application to the Safe Dams Act of 1973.

<u>Step 11. Design inlets, sediment forebay(s), outlet structures, maintenance access, and safety features.</u>

See subsection 4.3.1.3-D through H for more details.

<u>Step 12. Design vegetation</u>

A vegetation scheme for a water quality basin and its buffer should be prepared to indicate how aquatic and terrestrial areas will be stabilized and established with vegetation. See subsection 4.3.1.3-I for more details.

4.3.1.5 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.1.5 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of water quality basins as designed. It is the responsibility of the property owner to maintain all water quality facilities in accordance with the minimum design standards and other guidance provided in this manual. Consult with the local jurisdiction engineering department to determine if there are additional maintenance requirements.

This page provides guidance on maintenance activities that are typically required for water quality basins, along with a suggested frequency for each activity. Individual water quality basins may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the basin in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• After several storm events or an extreme storm event, inspect for: bank stability; signs of erosion; and damage to, or clogging of, the inlet/outlet structures and pilot channels.	As needed
• Inspect for: trash and debris; clogging of the inlet/outlet structures and any pilot channels; excessive erosion; sediment accumulation in the basin, forebay and inlet/outlet structures; tree growth on dam or embankment; the presence of burrowing animals; standing water where there should be none; vigor and density of the grass turf on the basin side slopes and floor; differential settlement; cracking; leakage; and slope stability.	Semi-annually
• Inspect that the inlet/outlet structures, pipes, sediment forebays, and upstream, downstream, and pilot channels are free of debris and are operational. • Check for signs of unhealthy or overpopulation of plants and/or fish (if utilized). • Note signs of algal growth or pollution, such as oil sheens, discolored water, or unpleasant odors. • Check sediment marker(s) for sediment accumulation in the facility and forebay. • Check for proper operation of control gates, valves or other mechanical devices. • Note changes to the wet basin or contributing drainage area as such changes may affect basin performance.	Annually
Maintenance Activities	**Suggested Schedule**
• Clean and remove debris from inlet and outlet structures. • Mow side slopes (embankment) and maintenance access. Periodic mowing is only required along maintenance rights-of-way and the embankment. The remaining basin buffer can be managed as a meadow (mowing every other year) or forest.	Monthly
• If wetland vegetation is included, remove invasive vegetation.	Semi-annually
• Repair damage to basin, outlet structures, embankments, control gates, valves, or other mechanical devices; repair undercut or eroded areas. • Remove pollutants or algal overgrowth as appropriate.	As Needed
• Perform wetland plant management and harvesting.	Annually (if needed)
• Remove sediment from the forebay. Sediments excavated from water quality basins that do not receive runoff from land uses that require a Special Pollution Abatement Permit (SPAP) 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 the basin receives discharge from a land use that requires a SPAP.	5 to 7 years or after 50% of the total forebay capacity has been lost
• Monitor sediment accumulations, and remove sediment when the basin volume has become reduced significantly or the basin is not providing a healthy habitat for vegetation and fish (if used). Discharges of basin water may be considered an illegal discharge, as per the local jurisdiction's requirements. Care should be exercised during basin drawdowns to prevent downstream discharge of sediments, anoxic water, or high flows with erosive velocities. The local jurisdiction should be notified before draining a water quality basin.	10 to 20 years or after 25% of the permanent pool volume has been lost

The property owner is encouraged to use the inspection checklist that is presented on the next page as a guide in the inspection and maintenance of water quality basins. Local authorities can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the water quality basin. Questions regarding water quality facility inspection and maintenance should be referred to the local engineering department.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
WATER QUALITY BASIN INSPECTION CHECKLIST

Location: ______________________________________ Owner Change since last inspection? Y N
Owner Name, Address, Phone: ______________________________________
Date: ___________ Time: ______________ Site conditions:______________________________________

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Embankment and Emergency Spillway		
Healthy vegetation?		
Growth of Woody Vegetation?		
Erosion on embankment?		
Animal burrows in embankment?		
Cracking, sliding, bulging of dam?		
Blocked or malfunctioning drains?		
Leaks or seeps on embankment?		
Obstructions of spillway(s)?		
Erosion in/around emergency spillway?		
Other (describe)?		
Inlet/Outlet Structures and Channels		
Clear of debris and functional?		
Trash rack clear of debris and functional?		
Sediment accumulation?		
Condition of concrete/masonry?		
Metal pipes in good condition?		
Control valve operation?		
Basin drain valve operation?		
Outfall channels function, not eroding?		
Other (describe)?		
Sediment Forebays		
Evidence of sediment accumulation?		
Permanent Pool Areas (if applicable)		
Undesirable vegetation growth?		
Visible pollution?		
Shoreline erosion?		
Erosion at outfalls into basin?		
Headwalls and endwalls in good condition?		
Encroachment by other activities?		
Evidence of sediment accumulation?		
Dry Basin Areas (if applicable)		
Vegetation adequate?		
Undesirable vegetation growth?		
Excessive sedimentation?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:________________________________ Inspector Name (printed)____________________________

4.3.1.6 Example Schematics

The example schematics for water quality wet basins presented in Figures 4-13 through 4-16 can be used to assist in the design of such BMPs.

Figure 4-13. Schematic of a Standard Wet Basin
(Source: modified from a graphic by the Center for Watershed Protection)

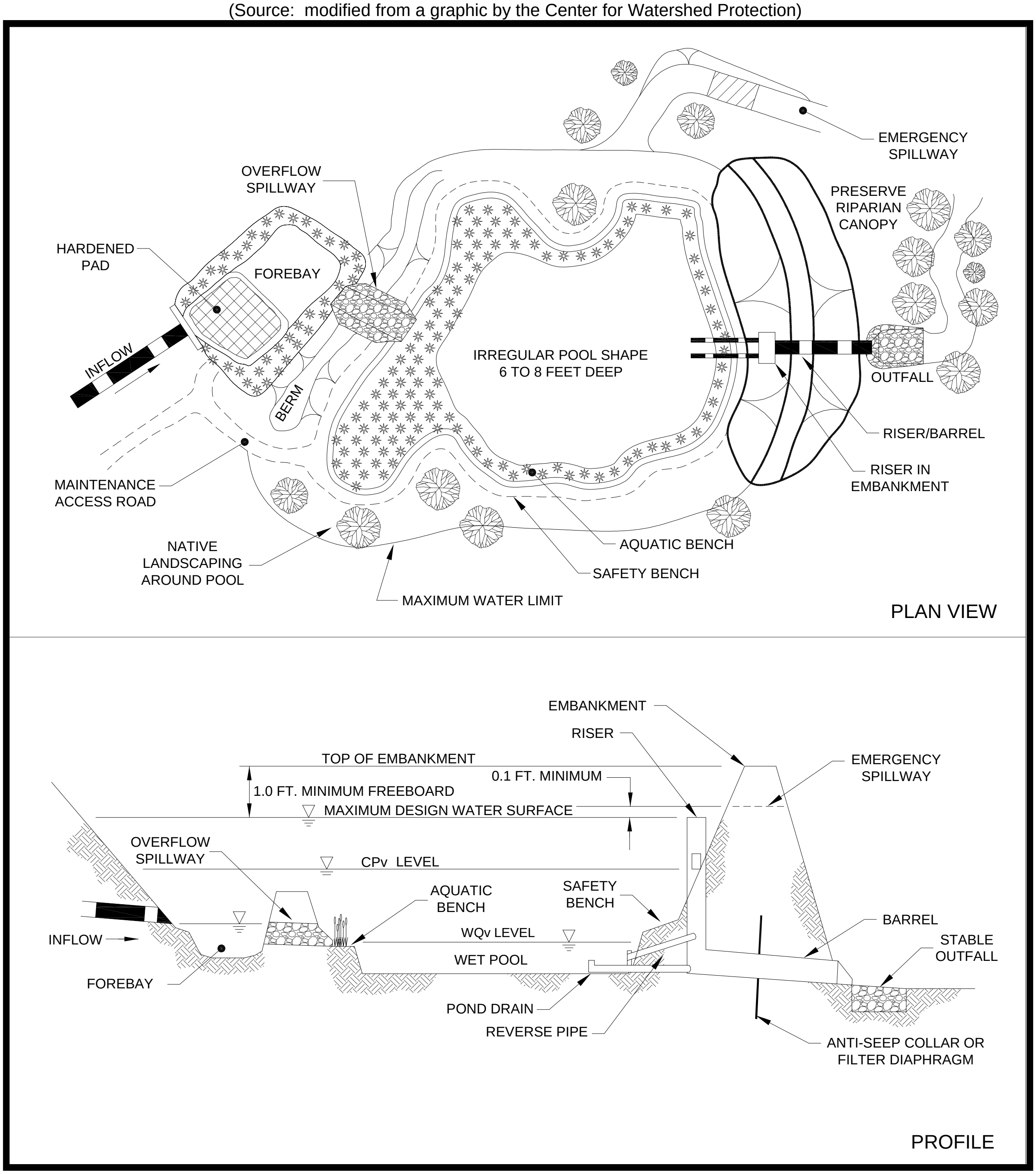


Figure 4-14. Schematic of a Wet Extended Detention Basin
(Source: modified from a graphic by the Center for Watershed Protection)

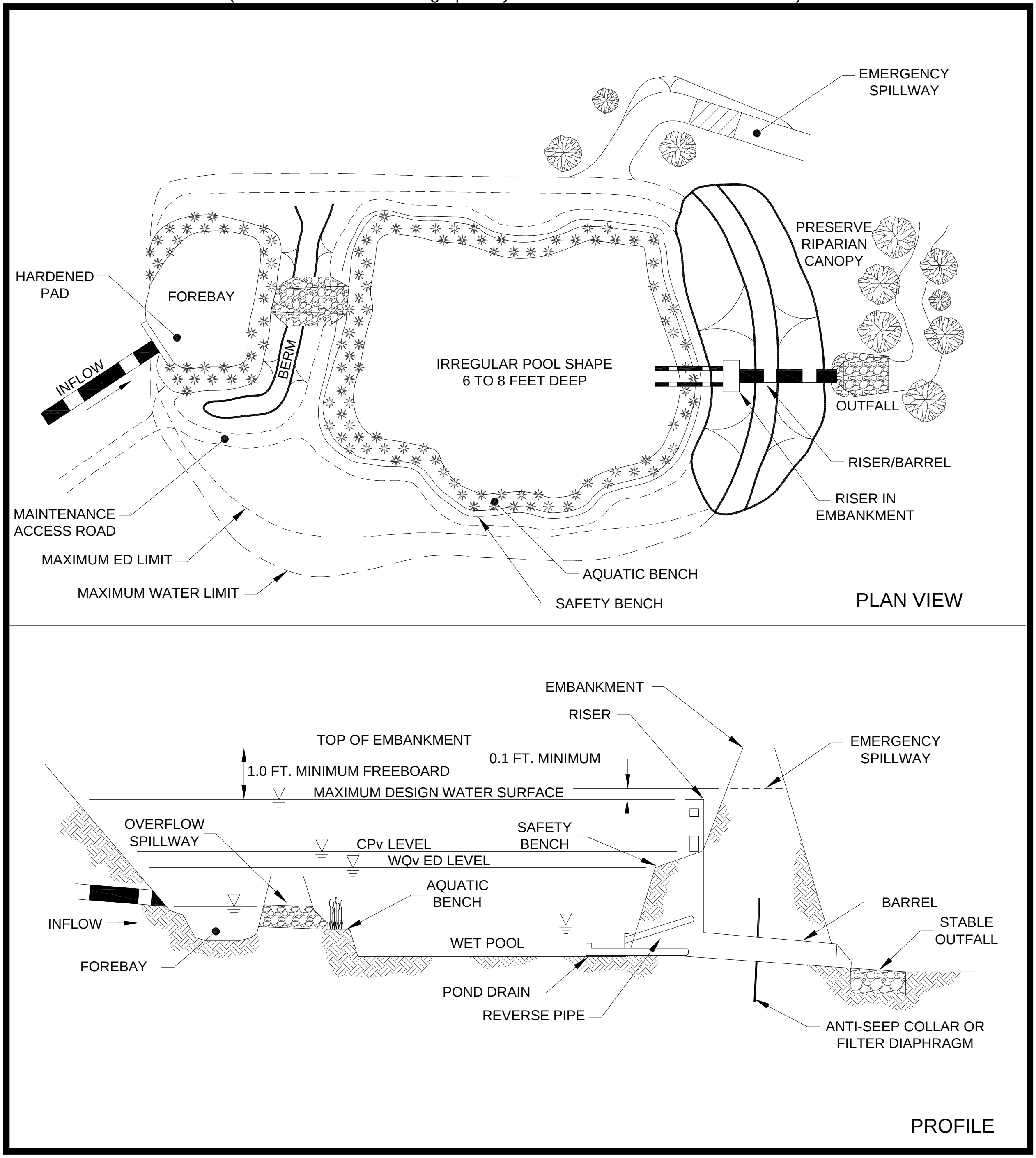


Figure 4-15. Schematic of a Micropool Extended Detention Basin
(Source: modified from a graphic by the Center for Watershed Protection)

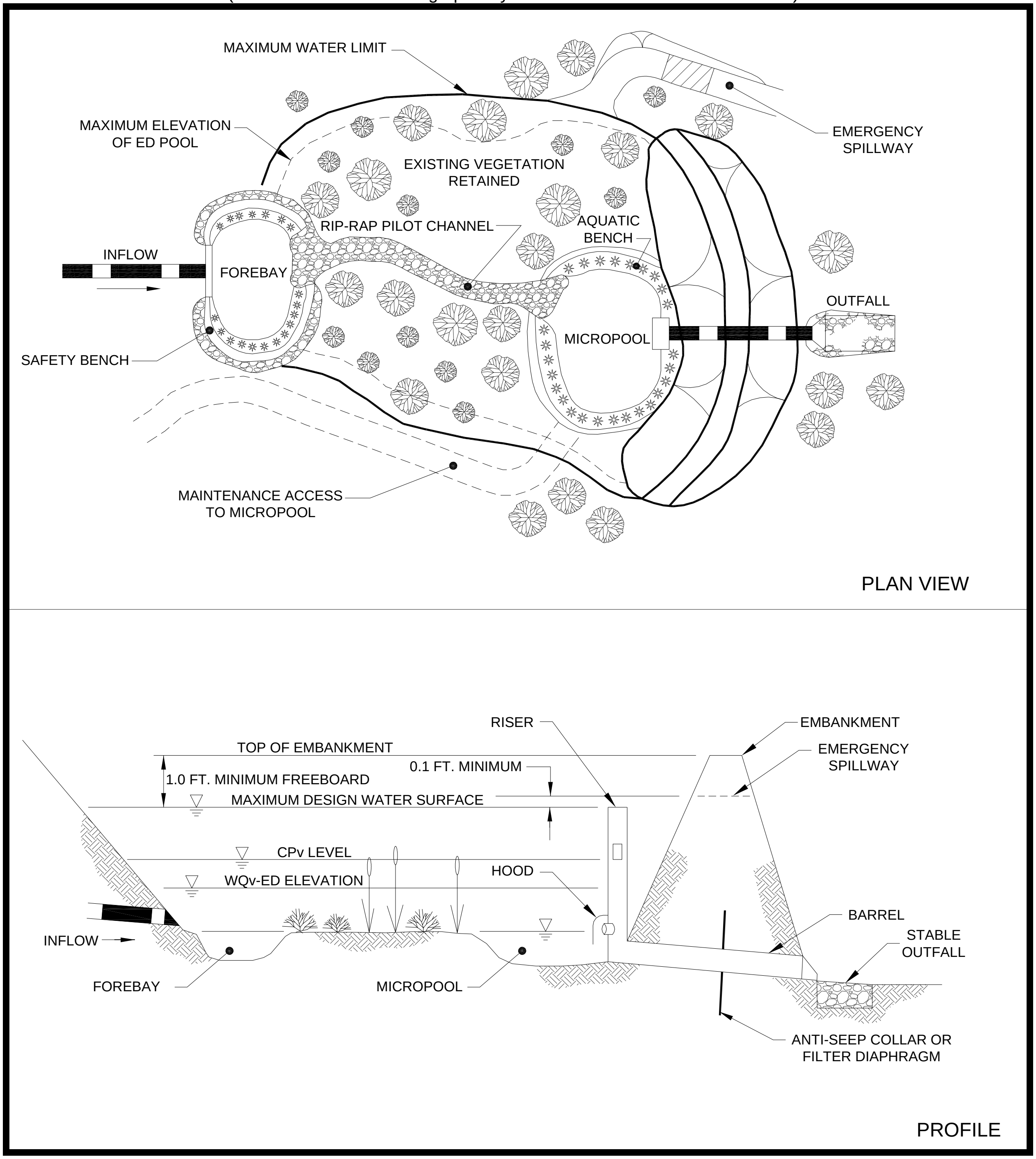
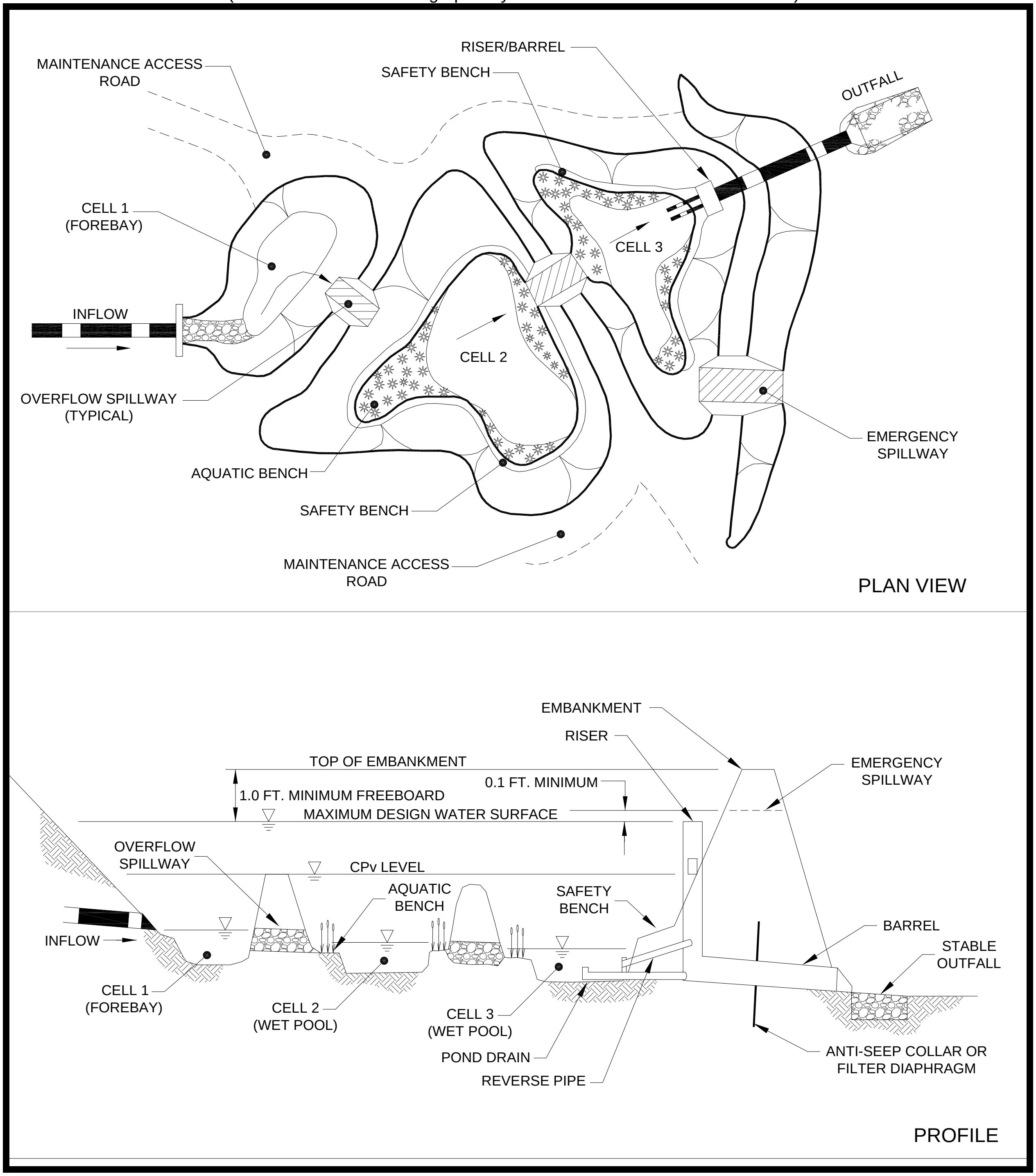


Figure 4-16. Schematic of a Multiple Basin System
(Source: modified from a graphic by the Center for Watershed Protection)



4.3.1.7 Design Form

Use of the following design procedure forms when designing a water quality wet basin is recommended. Proper use and completion of the form may allow a faster review of the basin design by the local engineering department.

Design Procedure Form: Water Quality Basins

PRELIMINARY HYDROLOGIC CALCULATIONS

1a. Compute WQv volume requirements
Compute Runoff Coefficient, Rv — Rv = ________
Compute WQv — WQv = ________ acre-ft

1b. Compute CPv — CPv = ________ acre-ft

STORMWATER BASIN DESIGN

2. Is the use of a stormwater basin appropriate? — ***See subsection 4.3.1.3***

3. Confirm additional design criteria and applicability. — ***See subsection 4.3.1.3 - J***

4. Pretreatment Volume (Forebay)
V_{pre} =(I)(.1")(1'/12") — V_{pre} = ________ acre-ft

5. Allocation of Permanent Pool Volume and ED Volume

Wet Basin — V_{pool}=1.0(WQv)-Vol_{pre} — V_{pool}= ________ acre-ft

Wet ED Basin — V_{pool}=0.5(WQv)-Vol_{pre} — V_{pool}= ________ acre-ft
V_{ED}=0.5(WQv)-Vol_{pre} — V_{ED}= ________ acre-ft

Micropool ED Basin — V_{pool}=(I)(.1")(1'/12") — V_{pool}= ________ acre-ft

6. Conduct grading design and determine storage available for permanent pool (and WQv-ED volume if applicable) — Prepare an elevation-storage table and curve using the average area method for computing volumes.

Elevation MSL	Area ft^2	Ave. Area ft^2	Depth ft	Volume ft^3	Cumulative Volume ft^3	Volume above Permanent Pool acre-ft

Design Procedure Form: Water Quality Basins (continued)

7. WQv Orifice Computations
   Average ED release rate (if applicable) — release rate= ______ cfs
   Average head, h= (ED elev.- Permanent Pool elev.) /2 — head= ______ ft
   Area of orifice from orifice equation — Area= ______ ft^2
   $Q=CA(2gh)^{0.5}$ — diameter ______ inches
   (C varies with orifice condition.)

   Establish CPv top elevation using stage-storage curve — CPv WSEL= ______ ft-NGVD
   Estimate orifice size — CPv orifice diameter = ______ inches
   Perform hydrograph routing to check detention time — centroid-centroid det. = ______ hours
   Iterate to final orifice size — Final CPv orifice diameter = ______ inches

8. Calculate required local peak discharge release rates and WSELs — Set up a stage-storage-discharge relationship

Elevation	Storage	Low Flow	Riser			Barrel		Emergency	Total
		WQv-ED	CPv_ED	High Storage		Inlet	Pipe	Spillway	Outflow
				Orif.	Weir				
MSL	acre-ft	H(ft) Q(cfs)	H(ft) Q(cfs)	H Q	H Q	H(ft) Q(cfs)	H(ft) Q(cfs)	H(ft) Q(cfs)	Q(cfs)

   Check inlet condition
   Check outlet conditions

   Use culvert design guidance from local municipality

9. Size emergency spillway using the local jurisdiction peak discharge and set top of embankment elevation and emergency spillway elevation based on $WSEL_{peak}$
   $Q_{ES}=Qp_{eak}$ ______ cfs
   $WSEL_{peak}=$ ______ ft
   El_{embank} ______ ft
   $El_{ES}=$ ______ ft

10. Investigate potential basin hazard classification — **See TN Safe Dams Act of 1973**

11. Design inlets, sediment forebays, outlet structures, maintenance access, and safety features — **See subsection 4.3.1.3 - D through H**

12. Design basin vegetation according to guidance provided in TVA Riparian Restoration webpage
    www.tva.com/river/landandshore/stabilization/index.htm

13. Verify peak flow control, water quality drawdown time and channel protection detention time

4.3.1.8 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

City of Nashville, Tennessee. *Metropolitan Nashville and Davidson County Stormwater Management Manual, Volume 4 Best Management Practices.* 2006.

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center, Accessed July 2005. *www.stormwatercenter.net*

Knox County, Tennessee.. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

4.3.1.9 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

United States Environmental Protection Agency. *Methodology for Analysis of Detention Basins for Control of Urban Runoff Quality.* 1986.

Urban Drainage and Flood Control District. *Urban Storm Drainage Criteria Manual – Volume 3 – Best Management Practices – Stormwater Quality.* Denver, Colorado, September 1992.

Walker, W. *Phosphorus Removal by Urban Runoff Detention Basins.* Lake and Reservoir Management, North American Society for Lake Management, 314, 1987.

Wanielista. M. *Final Report on Efficiency Optimization of Wet Detention Basins for Urban Stormwater Management.* University of Central Florida, 1989.

This page left intentionally blank

4.3.2 Conventional Dry Detention Basins

General Application Water Quality BMP

Description: A surface storage basin or facility designed to provide water quantity control through detention of stormwater runoff.

KEY CONSIDERATIONS

- Conventional dry detention basins provide control for overbank and extreme flood protection only. These basins are **not** intended to provide water quality treatment.
- Single basins are applicable for drainage areas up to 75 acres.
- Typically less costly than stormwater (wet) basins for equivalent flood storage, as less excavation is required.
- Must be used in conjunction with other BMPs that can adequately meet the minimum standard of 80% removal of TSS.
- Conventional dry detention basins can be used to provide recreational and other open space opportunities between storm runoff events when the basin bottom is dry.

MAINTENANCE REQUIREMENTS:

- Remove debris from inlet and outlet structures.
- Maintain side slopes and outlet structure.
- Monitor sediment accumulation and remove periodically.

STORMWATER MANAGEMENT APPLICABILITY

Stormwater Quality:	**No**
Channel Protection:	**Yes**
Detention/Retention:	**Yes**

Accepts hotspot runoff: *Yes, but two feet of separation distance required to water table when used in hotspot areas*

COST CONSIDERATIONS

Land Requirement:	**Med - High**
Capital Cost:	**Low**
Maintenance Burden:	**Low**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**No**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**10%**

4.3.2.1 General Description

Conventional dry detention basins are surface facilities intended to provide for the temporary storage of stormwater runoff to reduce downstream water quantity impacts. These facilities temporarily detain stormwater runoff, releasing the flow over a period of time. They are designed to completely drain following a storm event and are normally dry between rain events.

Dry detention basins can be utilized to provide flood protection for the locally regulated peak discharge storm event. Such basins provide limited pollutant removal benefits and are **not** intended for water quality treatment. Because conventional dry detention-only facilities can not provide a significant degree of water quality treatment, they must be used in conjunction with other structural controls that provide treatment of the water quality volume (WQv). Chapter 3 provides more information on treatment trains.

4.3.2.2 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of a dry detention basin. Dry detention basins that are not designed to these standards will not be approved. Consult with the local engineering department to determine if there are any variations to these criteria or additional standards that must be followed.

<u>A. LOCATION AND SITING</u>

- It is strongly recommended that dry detention basins be located where the topography allows for maximum runoff storage at minimum excavation or embankment construction costs. When locating a dry detention basin, the site designers should also consider the location and use of other land use features, such as planned open spaces and recreational areas, and should attempt to achieve a multi-use objective with the basin where this can be safely achieved.
- Detention basins shall not be located on unstable slopes or slopes greater than 15%.
- Flood protection controls for locally regulated peak discharges should be designed as final controls for on-site stormwater. Therefore, dry detention basins will typically be located downstream of structural stormwater BMPs that are designed to provide treatment of the water quality volume (WQv) and channel protection volume (CPv).
- A single dry detention basin shall not have a contributing drainage area greater than 75 acres unless specifically approved by the local municipality
- Dry detention basins shall not be located in a stream or any other navigable waters of the United States, including natural (i.e., not constructed) wetlands. Where an appeal or variance of this policy is desired, the property owner must obtain coverage under a Section 404 permit under the Clean Water Act and/or an Aquatic Resource Alteration Permit (ARAP) and provide proof of such coverage with the Water Quality Management Plan.
- Each conventional dry detention basin shall be placed in an easement that is recorded with the deed. The easement shall be defined at the outer edge of the safety bench, or a minimum of 15 feet from the normal water pool elevation (measured perpendicular from the pool elevation boundary) if a safety bench is not included in the basin design. The easement limit should be located no closer than as follows unless otherwise specified by the local jurisdiction:
  - From a public water system well – TDEC specified distance per designated category
  - From a private well – 50 feet; if the well is downgradient from a hotspot land use, as defined in this manual, then the minimum setback is 250 feet
  - From a septic system tank/leach field – 50 feet
- The minimum setback for habitable structures from the drainage easement shall be 15 feet. The first floor elevation (FFE) for any structure adjacent to the basin shall have an elevation no lower than 1 foot above the top of the berm.

- All utilities shall be located outside of the basin site.

B. GENERAL DESIGN

- A dry detention basin shall consist of the following elements, designed in accordance with the specifications provided in this section.
  (1) An outlet structure;
  (2) An emergency spillway;
  (3) Maintenance access; and,
  (4) Appropriate landscaping. (Consult landscaping standards/ordinances of the local jurisdiction for more specific information.)
- Dry detention basins shall be sized to attenuate peak discharges. Routing calculations must be used to demonstrate that the storage volume is adequate to meet the local jursidiction regulations.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

- Vegetated embankments shall be less than 20 feet in height. Side slopes shall not exceed 3:1 (horizontal to vertical) on one side of the basin to facilitate access for maintenance and repair. The remainder of the basin shall have side slopes no steeper than 2:1 although 3:1 is preferred. Benching of the slope is required for embankments greater than 10 feet in height and having greater than a 3:1 side slope. Riprap-protected embankments shall be no steeper than 2:1. Geotechnical slope stability analysis is recommended for embankments greater than 10 feet in height and is mandatory for embankment slopes steeper than those given above. All embankments must be designed to State of Tennessee guidelines for dam safety.
- The maximum depth of the basin shall not exceed 10 feet, without prior approval of the jurisdiction.
- Areas above the normal high water elevations of the detention basin shall be sloped toward the basin to allow drainage and to prevent standing water. Careful finish grading is required to avoid creation of upland surface depressions that may retain runoff. The basin bottom shall be graded toward the outlet to prevent standing water. A low flow or pilot channel across the facility bottom from the inlet to the outlet (often constructed with riprap) is recommended to convey low flows and prevent standing water conditions.

D. INLET and OUTLET STRUCTURES

Inflow channels shall be stabilized with flared riprap aprons, or the equivalent. A sediment forebay shall be provided for dry detention basins that are located in a treatment train with off-line water quality treatment structural controls. The sediment forebay shall be sized to contain 0.1 inch per impervious acre (363 ft^3) of contributing drainage and shall be no more than 4 to 6 feet deep.

- The outlet structure shall be sized for peak discharge controls (based upon hydrologic routing calculations) and can consist of a weir, orifice, outlet pipe, combination outlet, or other acceptable control structure. Small outlets that will be subject to clogging or are difficult to maintain shall not be permitted. Seepage control or anti-seep collars shall be provided for all outlet pipes per the regulations of the local jurisdiction.
- Water shall not be discharged from a detention basin in an erosive manner. Riprap, plunge pads or pools, or other energy dissipators shall be placed at the outlet of the barrel to prevent scouring and erosion. If a basin outlet discharges immediately to a channel that carries dry weather flow, care should be taken to minimize disturbance along the downstream channel and streambanks, and to reestablish a forested riparian zone in the shortest possible distance (if the downstream area is located in a vegetated buffer).

E. EMERGENCY SPILLWAY

- An emergency spillway shall be included per regulations of the local jurisdiction.

F. MAINTENANCE ACCESS

- A maintenance right-of-way or easement having a minimum width of 20 feet shall be provided to the basin from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.
- The maintenance access shall extend to the forebay (if included) and outlet works, and, to the extent feasible, be designed to allow vehicles to turn around.

G. SAFETY FEATURES

- A safety bench shall be provided for embankments greater than 10 feet in height and having greater than a 3:1 side slope. For large basins, the safety bench shall extend no less than 15 feet outward from the normal water edge to the toe of the basin side slope. The slope of the safety bench shall not exceed 6%.
- All embankments and spillways shall be designed to TDEC rules and regulations as applied to the Safe Dams Act of 1973, where applicable.
- The property owner may consider fencing the basin for the purpose of safety management.
- All outlet structures shall be designed so as not to permit access by children. The posting of warning signs is encouraged near the basin to prohibit swimming and fishing in the facility.

H. LANDSCAPING

- All areas of the basin shall be stabilized with vegetation to prevent the occurrence of erosion.
- Woody vegetation shall not be planted on the embankment or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.
- Vegetated buffers, as defined and described in Chapter 6 of this manual, are not required for dry detention basins. However, it should be noted that vegetated buffers can be utilized for water quality treatment and can result in a volume reduction that reduces the WQv. The criteria for the vegetated buffer reduction are presented in Chapter 5 of this manual.

4.3.2.3 Design Procedures

In general, site designers should perform the following design procedures when designing a dry detention basin.

Step 1. Compute runoff control volumes.

> Calculate pre- and post-development peak discharges and runoff volumes. Consult local regulations for peak discharge control (i.e., detention) requirements.

Step 2. Confirm design criteria and applicability.

> Consider any special site-specific design conditions/criteria from subsection 4.3.2.2. Check with the local jurisdiction, TDEC, or other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply to the site.

Step 3. Determine basin location and preliminary geometry.

> This step involves initially designing the grading of the basin (establishing contours) and determining the elevation-storage relationship for the basin. Include consideration of a safety bench, if used or required by the local jurisdiction.

Step 4. Calculate peak discharge release rates and water surface elevations for flood control (i.e., detention)

Set up a stage-storage-discharge relationship for the control structure for the peak discharge control storm orifices.

Step 5. Design embankment(s) and spillway(s)

Size emergency spillway per the regulations of the local jurisdiction.

Step 6. Investigate potential basin hazard classification

The design and construction of dry detention basins are required to follow the latest version of the TDEC Rules and Regulations Application to the Safe Dams Act of 1973.

Step 7. Design inlets, outlet structures, maintenance access, and safety features.

See subsection 4.3.2.2 for more details.

Step 8. Design vegetation

A vegetation scheme for the detention basin should be prepared to indicate how the basin bottom, side slopes and embankments will be stabilized and established with vegetation.

This space intentionally left blank

4.3.2.4 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.2.4 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of the detention basin as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local jurisdiction has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for detention basins, along with a suggested frequency for each activity. Individual basins may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the basin in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• After several storm events or an extreme storm event, inspect for: bank stability; signs of erosion; and damage to, or clogging of, the outlet structures and pilot channels.	As Needed
• Inspect for: trash and debris; clogging of the outlet structures and any pilot channels; excessive erosion; sediment accumulation in the basin and inlet/outlet structures; tree growth on dam or embankment; the presence of burrowing animals; standing water where there should be none; vigor and density of the grass turf on the basin side slopes and floor; differential settlement; cracking; leakage; and slope stability.	Semi-annually
• Inspect that the outlet structures, pipes, and downstream and pilot channels are free of debris and are operational. • Note signs of pollution, such as oil sheens, discolored water, or unpleasant odors. • Check for sediment accumulation in the facility. • Check for proper operation of control gates, valves or other mechanical devices.	Annually
Maintenance Activities	**Suggested Schedule**
• Clean and remove debris from inlet and outlet structures. • Mow side slopes (embankment) and maintenance access. Periodic mowing is only required along maintenance rights-of-way and the embankment.	Monthly or as needed
• Repair and revegetate eroded areas. • Remove vegetation that may hinder the operation of the basin. • Repair damage to the basin, outlet structures, embankments, control gates, valves, or other mechanical devices; repair undercut or eroded areas.	As Needed
• Monitor sediment accumulations, and remove sediment when the basin volume has become reduced significantly.	As Needed (typically every 20 to 50 years)

The property owner is encouraged to use the inspection checklist that is presented on the next page as a guide in the inspection and maintenance of conventional dry detention basins. Local authorities can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the dry ED basin. Questions regarding stormwater facility inspection and maintenance should be referred to the local engineering department.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
CONVENTIONAL DRY DETENTION BASIN INSPECTION CHECKLIST

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: ___________ Time: ______________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Embankment and Emergency Spillway		
Vegetation coverage adequate?		
Erosion on embankment?		
Animal burrows in embankment?		
Cracking, sliding, bulging of dam?		
Blocked or malfunctioning drains?		
Leaks or seeps on embankment?		
Obstructions of spillway(s)?		
Erosion in/around emergency spillway?		
Other (describe)?		
Inlet/Outlet Structures and Channels		
Clear of debris and functional?		
Trash rack clear of debris and functional?		
Sediment accumulation?		
Condition of concrete/masonry?		
Metal pipes in good condition?		
Control valve operational?		
Basin drain valve operational?		
Outfall channels function, not eroding?		
Other (describe)?		
Basin Bottom		
Vegetation adequate?		
Undesirable vegetation growth?		
Excessive sedimentation?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

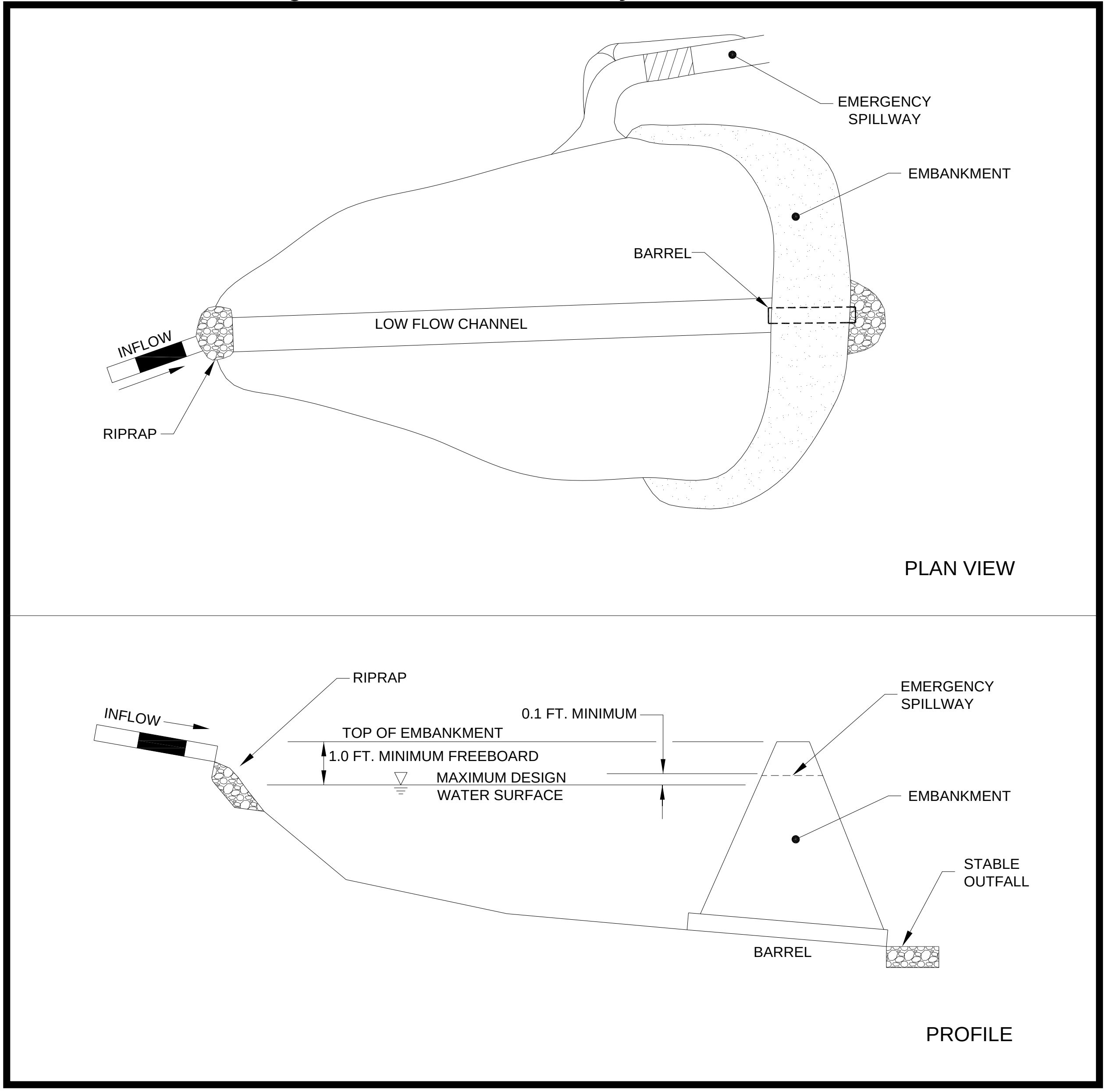
Corrective Action Needed	Due Date

Inspector Signature:_________________________________ Inspector Name (printed)___________________________

4.3.2.5 Example Schematic

The example schematics for dry detention basins presented in Figure 4-17 can be used to assist in the design of such a BMP.

Figure 4-17. Schematic of Dry Detention Basin



4.3.2.6 Design Form

Use of the following design procedure forms when designing a conventional dry detention basin is recommended. Proper use and completion of the form may allow a faster review of the basin design by the local engineering department.

Design Procedure Form: Dry Detention Basins

PRELIMINARY HYDROLOGIC CALCULATIONS

1 Compute storage volume required for locally regulated storm events — storage = ________ acre-ft; storage = ________ acre-ft

DRY DETENTION BASIN DESIGN

2. Confirm design criteria and applicability. — ***See Section 4.3.2.2***

3. Conduct grading design and determine storage available — Prepare an elevation-storage table and curve using the average area method for computing volumes.

Elevation	Area	Ave. Area	Depth	Volume	Cumulative Volume
MSL	ft^2	ft^2	ft	ft^3	ft^3

4. Calculate required local jurisdiction peak discharge release rates and WSELs — Set up a stage-storage-discharge relationship

Elevation	Storage	Low Flow	Riser			Barrel		Emergency	Total
		WQv-ED	CPv.ED	High Storage		Inlet	Pipe	Spillway	Storage
				Orif.	Weir				
MSL	acre-ft	H(ft) Q(cfs)	H(ft) Q(cfs)	H Q	H Q	H(ft) Q(cfs)	H(ft) Q(cfs)	H(ft) Q(cfs)	acre-ft

Check inlet condition
Check outlet conditions — **Use culvert design guidance from local municipality**

5. Size emergency spillway using the local municipality peak discharge and set top of embankment elevation and emergency spillway elevation based on $WSEL_{peak}$

Q_{ES}=Qp_{peak} ________ cfs
$WSEL_{peak}$= ________ ft
El_{embank}= ________ ft
El_{ES}= ________ ft

6. Investigate potential basin hazard classification — **See TN Safe Dams Act of 1973**

7. Design inlets, sediment forebays, outlet structures, maintenance access, and safety features — **See Section 4.3.2.2**

8. Design basin vegetation

4.3.2.7 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

City of Nashville, Tennessee. *Metropolitan Nashville and Davidson County Stormwater Management Manual, Volume 4 Best Management Practices.* 2006.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

4.3.2.8 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Merritt, F.S., Loftin, M.K., Ricketts, J.T. *Standard Handbook for Civil Engineers*. Fourth Edition McGraw-Hill, 1996.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

4.3.3 Dry Extended Detention Basins

General Application Water Quality BMP

Description: A surface storage basin or facility designed to provide water quantity and quality control through detention of stormwater runoff.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Single basins will have a maximum contributing drainage area of 75 acres.
- A sediment forebay or equivalent upstream pretreatment must be provided.
- Minimum flow length to width ratio for the basin is 1.5:1. The basin shall be sized to detain the volume of runoff to be treated for a minimum of 24 hours.
- Side slopes to the basin shall not exceed 3:1 (h:v) on one side of the basin to facilitate access. Slopes as steep as 2:1 will be allowed for other areas, with proper stabilization.

ADVANTAGES / BENEFITS:

- Moderate removal rate of urban pollutants.
- High community acceptance.
- Useful for water quality treatment and flood control.

DISADVANTAGES / LIMITATIONS:

- Potential for thermal impacts/downstream warming.
- Dam height restrictions for high relief areas.
- Basin drainage can be problematic for low relief terrain.

MAINTENANCE REQUIREMENTS:

- Remove debris from inlet and outlet structures.
- Maintain side slopes and outlet structure.
- Remove invasive vegetation.
- Monitor sediment accumulation and remove periodically.

OTHER CONSIDERATIONS:

- Outlet clogging
- Safety bench
- Landscaping

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**Yes**
Detention/Retention:	**Yes**

Accepts hotspot runoff: *Yes, but two feet of separation distance required to water table when used in hotspot areas*

COST CONSIDERATIONS

Land Requirement:	**Med - High**
Capital Cost:	**Low**
Maintenance Burden:	**Low**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**No**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**60%**

4.3.3.1 General Description

Dry extended detention (ED) basins are surface facilities that provide for the temporary storage of stormwater runoff for some minimum time (e.g., 24 to 72 hours) to allow suspended sediments and other associated pollutants to settle to the basin bottom, and therefore, not discharge to downstream channels. Dry ED basins provide moderate treatment of the water quality volume (WQv), are useful for control of the channel protection volume (CPv), and can provide overbank flood protection and extreme flood protection as well.

4.3.3.2 Pollutant Removal Capabilities

Dry ED basins are presumed capable of removing at least 60% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the specifications provided in this manual. The TSS removal performance can be reduced by poor design, construction or maintenance.

Additionally, research has shown that use of dry ED basins will have moderate benefits beyond the removal of TSS, such as the removal of other pollutants (i.e. phosphorous, nitrogen, fecal coliform and heavy metals), as well, which is useful information should the pollutant removal criteria change in the future.

For additional information and data on dry ED basins, see the National Pollutant Removal Performance Database (2nd Edition) available at www.stormwatercenter.net and the International Stormwater Best Management Practices Database at www.bmpdatabase.org.

Because dry ED basins cannot alone provide adequate treatment of the water quality volume, they must be utilized in a treatment train approach with other structural controls to achieve the goal of 80% removal of total suspended solids (TSS). Chapter 3 provides more information on treatment trains.

4.3.3.3 Planning and Design Standards

The following criteria shall be considered **minimum** design standards for the design of a dry ED basin. Dry ED basins that are not designed to these standards will not be approved. Consult with the local engineering department to determine if there are any variations to these criteria or additional standards that must be followed.

<u>A. LOCATION AND SITING</u>

- It is strongly recommended that dry ED basins be located where the topography allows for maximum runoff storage at minimum excavation or embankment construction costs. When locating a dry ED basin, the site designers should also consider the location and use of other land use features, such as planned open spaces and recreational areas, and should attempt to achieve a multi-use objective with the basin where this can be safely achieved.
- Dry ED basins shall not be located on unstable slopes or slopes greater than 15%.
- Flood protection controls for control of the peak discharges should be designed as final controls for on-site stormwater. Because most dry ED basins will be used for flood protection and are not capable of achieving the required 80% TSS removal standard, they will typically be located downstream of structural stormwater BMPs that are used in conjunction with the dry ED basin to provide 80% treatment of the WQv.
- A single dry ED basin shall not have a contributing drainage area greater than 75 acres unless specifically approved by the Director.
- Dry ED basins shall not be located in a stream or any other navigable waters of the United States, including natural (i.e., not constructed) wetlands. Where an appeal or variance of this policy is desired, the property owner must obtain coverage under a Section 404 permit under the Clean Water Act and/or an Aquatic Resource Alteration Permit (ARAP) and provide proof of such coverage with the Water Quality Management Plan.

- Each dry ED basin shall be placed in an easement. The easement shall be defined at the outer edge of the safety bench, or a minimum of 15 feet from the normal water pool elevation (measured perpendicular from the pool elevation boundary) if a safety bench is not included in the basin design. The easement limit should be located no closer than as follows unless otherwise specified by the local regulations:
    - From a public water system well – TDEC specified distance per designated well category
    - From a private well – 50 feet; if the well is downgradient from a hotspot land use, as defined in this manual, then the minimum setback is 250 feet
    - From a septic system tank/leach field – 50 feet
- The minimum setback for habitable structures from the easement shall be 15 feet. The first floor elevation (FFE) for any structure adjacent to the basin shall have an elevation no lower than 1 foot above the top of the berm.
- All utilities shall be located outside of the dry ED basin.

B. GENERAL DESIGN

- A dry ED basin shall consist of the following elements, designed in accordance with the specifications provided in this section:
    (1) An outlet structure;
    (2) An emergency spillway;
    (3) A sediment forebay;
    (4) Maintenance access;
    (5) Appropriate landscaping.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

- Vegetated embankments shall be less than 20 feet in height. Side slopes shall not exceed 3:1 (horizontal to vertical) on one side of the basin to facilitate access for maintenance and repair. The remainder of the basin shall have side slopes no steeper than 2:1 although 3:1 is preferred. Benching of the slope is required for embankments greater than 10 feet in height and having greater than a 3:1 side slope. Riprap-protected embankments shall be no steeper than 2:1. Geotechnical slope stability analysis is recommended for embankments greater than 10 feet in height and is mandatory for embankment slopes steeper than those given above. All embankments must be designed to State of Tennessee guidelines for dam safety.
- The maximum depth of the basin shall not exceed 10 feet.
- Areas above the normal high water elevations of the dry ED basin shall be sloped toward the basin to allow drainage and to prevent standing water. Careful finish grading is required to avoid creation of upland surface depressions that may retain runoff. The basin bottom shall be graded toward the outlet to prevent standing water. A low flow or pilot channel across the facility bottom from the inlet to the outlet (often constructed with riprap) is recommended to convey low flows and prevent standing water conditions.

D. PRETREATMENT / INLETS

- A sediment forebay shall be provided for dry ED basins that are located in a treatment train with other water quality treatment structural controls. The sediment forebay is utilized to remove incoming sediment from the stormwater flow prior to dispersal into the larger basin area. The forebay shall consist of a separate cell, formed by an acceptable barrier. A forebay must be provided at each inlet to the dry ED basin, unless the inlet provides less than 10% of the total design storm inflow to the basin.
- The sediment forebay shall be sized to contain 0.1 inch per impervious acre (363 ft^3) of contributing drainage and shall be no more than 4 to 6 feet deep.

- A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.
- Inflow channels to the forebay shall be stabilized with flared riprap aprons, or the equivalent. Exit velocities of discharges from the forebay to the basin must be non-erosive.

E. OUTLET STRUCTURES

- Flow control from a dry ED basin that is used for control of the WQv, CPv and the locally regulated peak discharges is typically accomplished with the use of a riser and barrel. The riser is a vertical pipe or inlet structure that is located at the base of the basin. The outlet barrel is a horizontal pipe attached to the riser that conveys flow under the embankment. The riser shall be located within the basin embankment for maintenance access, safety and aesthetics.
- A number of outlets at varying depths in the riser provide internal flow control for routing of the WQv, CPv, and the locally regulated peak discharges. The number of orifices can vary and is usually a function of the basin design. A dry ED basin riser configuration is typically comprised of an outlet that provides water quality (WQv), a channel protection (CPv) outlet (usually an orifice), and outlets for the locally controlled peak events (often a slot or weir). All outlets are protected by trash racks to prevent clogging. The channel protection orifice is sized to release the channel protection storage volume for a minimum 24-hour period, centroid to centroid.
- The water quality/channel protection outlet can be fitted with adjustable gate valves or another mechanism that can be used to adjust detention time.
- After entering the riser, flow is conveyed through the barrel and is discharged downstream. Anti-seep collars shall be installed on the outlet barrel to reduce the potential for pipe or embankment failure.
- Seepage control or anti-seep collars shall be provided for all outlet pipes.
- Water shall not be discharged from a dry ED basin in an erosive manner. Riprap, plunge pads or pools, or other energy dissipators shall be placed at the outlet of the barrel to prevent scouring and erosion. If a basin outlet discharges immediately to a channel that carries dry weather flow, care should be taken to minimize disturbance along the downstream channel and streambanks, and to reestablish a forested riparian zone in the shortest possible distance (if the downstream area is located in a vegetated buffer).

F. EMERGENCY SPILLWAY

- An emergency spillway shall be included per regulations of the local jurisdiction.

G. MAINTENANCE ACCESS

- A maintenance right-of-way or easement having a minimum width of 20 feet shall be provided to the basin from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.
- The maintenance access shall extend to the forebay (if included) and outlet structure, and, to the extent feasible, be designed to allow vehicles to turn around.

H. SAFETY FEATURES

- A safety bench shall be provided for embankments greater than 10 feet in height and having greater than a 3:1 side slope. For large basins, the safety bench shall extend no less than 15 feet outward from the normal water edge to the toe of the basin side slope. The slope of the safety bench shall not exceed 6%.
- All embankments and spillways shall be designed to TDEC rules and regulations as applied to the Safe Dams Act of 1973, where applicable.
- The property owner may consider fencing the basin for the purpose of safety management.

- All outlet structures shall be designed so as not to permit access by children. The posting of warning signs is encouraged near the basin to prohibit swimming and fishing in the facility.

I. LANDSCAPING

- All areas of the basin shall be stabilized with appropriate vegetation to prevent the occurrence of erosion.
- Woody vegetation shall not be planted on the embankment or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.
- Vegetated buffers, as defined and described in Chapter 6 of this manual, are not required for dry ED basins. However, it should be noted that vegetated buffers can be utilized for water quality treatment and can result in a volume reduction that reduces the WQv. The criteria for the vegetated buffer reduction are presented in Chapter 5 of this manual.

4.3.3.4 Design Procedures

In general, site designers should perform the following design procedures when designing a dry ED basin.

Step 1. Compute runoff control volumes

Calculate WQv, CPv, and pre- and post-development peak discharges and runoff volumes for the storms specified by the local jurisdiction. The calculation of WQv and CPv is presented in Chapter 3 of this manual. Consult local regulations for peak discharge control (i.e., detention) requirements.

Step 2. Confirm design criteria and applicability

Consider any special site-specific design conditions/criteria from subsection 4.3.3.3. Check with the local jurisdiction, TDEC or other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply to the site.

Step 3. Determine pretreatment volume

A sediment forebay is provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the basin. The forebay should be sized to contain 0.1 inch per impervious acre (363 ft^3) of contributing drainage and should be 4 to 6 feet deep.

Step 4. Determine basin location and preliminary geometry

This step involves initially designing the grading of the basin (establishing contours) and determining the elevation-storage relationship for the basin. Include safety bench, if required or used. See subsection 4.3.3.3 for more details.

Step 5. Compute extended detention orifice release rate(s) and size(s), and establish CPv elevation

The water quality orifice is sized to release the calculated WQv over a minimum 24 hour period and should be adequately protected from clogging by an acceptable external trash rack. The CPv elevation is then determined from the stage-storage relationship. The invert of the channel protection orifice is located at the water quality extended detention elevation, and the orifice is sized to release the channel protection storage volume over a 24-hour period, centroid to centroid.

Step 6. Calculate peak discharge release rates and water surface elevations

Set up a stage-storage-discharge relationship for the control structure for the extended detention and the locally regulated peak discharge orifices.

Step 7. Design embankment(s) and spillway(s)

An emergency spillway shall be included per regulations of the local jurisdiction.

Step 8. Investigate potential basin hazard classification

The design and construction of stormwater management basins are required to follow the latest version of the TDEC Rules and Regulations Application to the Safe Dams Act of 1973.

Step 9. Design inlets, sediment forebay(s), outlet structures, maintenance access, and safety features.

See subsection 4.3.3.3 for more details.

Step 10. Design vegetation

A vegetation scheme for the dry ED basin should be prepared to indicate how the basin bottom, side slopes and embankment will be stabilized and established with vegetation.

This space intentionally left blank

4.3.3.5 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.3.5 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of the dry ED basin as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local jurisdiction has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for dry ED basins, along with a suggested frequency for each activity. Individual basins may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e.., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the basin in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• After several storm events or an extreme storm event, inspect for: bank stability; signs of erosion; and damage to, or clogging of, the outlet structures and pilot channels.	As needed
• Inspect for: trash and debris; clogging of the outlet structures and any pilot channels; excessive erosion; sediment accumulation in the basin, forebay and inlet/outlet structures; tree growth on dam or embankment; the presence of burrowing animals; standing water where there should be none; vigor and density of the grass turf on the basin side slopes and floor; differential settlement; cracking; leakage; and slope stability.	Semi-annually
• Inspect that the outlet structures, pipes, and downstream and pilot channels are free of debris and are operational. • Note signs of pollution, such as oil sheens, discolored water, or unpleasant odors. • Check for sediment accumulation in the facility. • Check for proper operation of control gates, valves or other mechanical devices.	Annually
Maintenance Activities	**Suggested Schedule**
• Clean and remove debris from inlet and outlet structures. • Mow side slopes (embankment) and maintenance access. Periodic mowing is only required along maintenance rights-of-way and the embankment.	Monthly or as needed
• Repair and revegetate eroded areas. • Remove vegetation that may hinder the operation of the basin. • Repair damage to basin, outlet structures, embankments, control gates, valves, or other mechanical devices; repair undercut or eroded areas.	As Needed
• Monitor sediment accumulations, and remove sediment when the basin volume has become reduced significantly.	As Needed (typically every 20 to 50 years)

The property owner is encouraged to use the inspection checklist that is presented on the next page as a guide in the inspection and maintenance of dry ED basins. Local authorities can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the dry ED basin. Questions regarding stormwater facility inspection and maintenance should be referred to the local engineering department.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
DRY EXTENDED DETENTION BASIN INSPECTION CHECKLIST

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: __________ Time: _____________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Embankment and Emergency Spillway		
Vegetation coverage adequate?		
Growth of woody vegetation?		
Erosion on embankment?		
Animal burrows in embankment?		
Cracking, sliding, bulging of dam?		
Blocked or malfunctioning drains?		
Leaks or seeps on embankment?		
Obstructions of spillway(s)?		
Erosion in/around emergency spillway?		
Other (describe)?		
Inlet/Outlet Structures and Channels		
Clear of debris and functional?		
Trash rack clear of debris and functional?		
Sediment accumulation?		
Condition of concrete/masonry?		
Metal pipes in good condition?		
Control valve operational?		
Basin drain valve operational?		
Outfall channels function, not eroding?		
Other (describe)?		
Basin Bottom		
Vegetation adequate?		
Undesirable vegetation growth?		
Excessive sedimentation?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

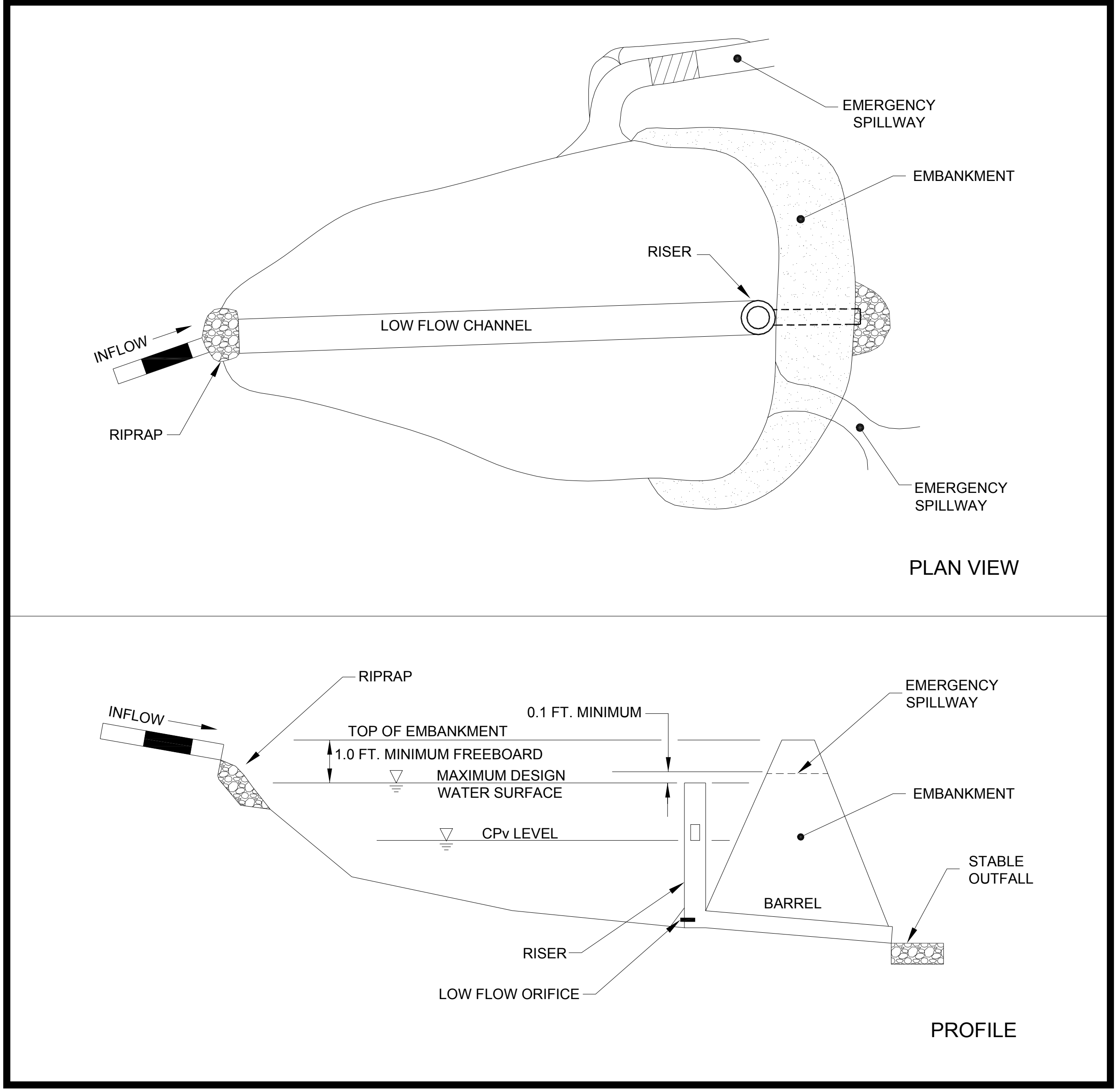
Corrective Action Needed	Due Date

Inspector Signature:______________________________ Inspector Name (printed)_________________________

4.3.3.6 Example Schematic

The example schematic for a dry extended detention basin presented in Figure 4-18 can be used to assist in the design of such BMPs.

Figure 4-18. Schematic of Dry Extended Detention Basin



4.3.3.7 Design Form

Use of the following design procedure forms when designing a dry extended detention basin is recommended. Proper use and completion of the form may allow a faster review of the basin design by the local engineering department.

Design Procedure Form: Dry Extended Detention Basins

PRELIMINARY HYDROLOGIC CALCULATIONS

1a. Compute WQv volume requirements
Compute Runoff Coefficient, Rv — Rv = ________
Compute WQv — WQv = ________ acre-ft

1b. Estimate CPv — CPv = ________ acre-ft

DRY EXTENDED DETENTION BASINS DESIGN

2. Is the use of a dry extended detention basin appropriate? — ***See subsections 4.3.3.1***

3. Confirm design criteria and applicability. — ***See subsection 4.3.3.3***

4. Pretreatment Volume (Forebay)
V_{pre} =(I)(.1")(1'/12") — V_{pre} = ________ acre-ft

5. Conduct grading design and determine storage available — Prepare an elevation-storage table and curve using the average area method for computing volumes.

Elevation MSL	Area ft^2	Ave. Area ft^2	Depth ft	Volume ft^3	Cumulative Volume ft^3

Design Procedure Form: Dry Extended Detention Basins (continued)

6. WQv Orifice Computations
   Average ED release rate (if applicable) — release rate= ____________ cfs
   Average head, h= (ED elev.- Permanent Pool elev.) /2 — head= ____________ ft
   Area of orifice from orifice equation — Area= ____________ ft2
   $Q=CA(2gh)^{0.5}$ C varies with orifice condition — diameter ____________ inches

   Establish CPv top elevation using stage-storage curve — CPv WSEL= ____________ ft-NGVD
   Estimate orifice size — CPv orifice diameter = ____________ inches
   Perform hydrograph routing to check detention time — centroid-centroid det. = ____________ hours
   Iterate to final orifice size — Final CPv orifice diameter = ____________ inches

7. Calculate required local municipality peak discharge release rates and WSELs — Set up a stage-storage-discharge relationship

Elevation	Storage	Low Flow	Riser			Barrel		Emergency	Total
		WQv-ED	CPv_ED	High Storage		Inlet	Pipe	Spillway	Storage
				Orif.	Weir				
MSL	acre-ft	H(ft) Q(cfs)	H(ft) Q(cfs)	H Q	H Q	H(ft) Q(cfs)	H(ft) Q(cfs)	H(ft) Q(cfs)	acre-ft

   Check inlet condition
   Check outlet conditions

   Use culvert design guidance from local municipality

8. Size emergency spillway using the local municipality peak discharge and set top of embankment elevation and emergency spillway elevation based on $WSEL_{peak}$

   $Q_{ES}=Qp_{peak}$ ____________ cfs
   $WSEL_{peak}$= ____________ ft
   El_{embank}= ____________ ft
   El_{ES}= ____________ ft

9. Investigate potential basin hazard classification — **See TN Safe Dams Act of 1973**

10. Design inlets, sediment forebays, outlet structures, maintenance access, and safety features — ***See subection 4.3.3.3***

11. Design vegetation according to guidance provided in TVA Riparian Restoration webpage
    www.tva.com/river/landandshore/stabilization/index.htm

13. Verify peak flow control, water quality drawdown time and channel protection detention time

4.3.3.8 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center, Accessed July 2005. www.stormwatercenter.net

City of Nashville, Tennessee. *Metropolitan Nashville and Davidson County Stormwater Management Manual, Volume 4 Best Management Practices.* 2006.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

4.3.3.9 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

United States Environmental Protection Agency. *Methodology for Analysis of Detention Basins for Control of Urban Runoff Quality.* 1986.

Urban Drainage and Flood Control District. *Urban Storm Drainage Criteria Manual – Volume 3 – Best Management Practices – Stormwater Quality.* Denver, Colorado, September 1992.

Walker, W. *Phosphorus Removal by Urban Runoff Detention Basins.* Lake and Reservoir Management, North American Society for Lake Management, 314, 1987.

4.3.4 Stormwater Wetlands

General Application Water Quality BMP

Description: A constructed wetland system used for stormwater management. Runoff volume is both stored and treated in the wetland facility.

KEY DESIGN CONSIDERATIONS

DESIGN GUIDELINES:

- Minimum contributing drainage area of 25 acres; 5 acres for a pocket wetland.
- Minimum dry weather flow path of 2:1 (length:width) should be provided from inflow to outflow.
- Minimum of 35% of total surface area should have a depth of 6 inches or less; 10 to 20% of surface area should be deep pool (1.5- to 6-foot depth).
- Use in Hydrologic group 'A' and 'B' soils or in areas of karst topography may require a liner.

ADVANTAGES / BENEFITS:

- Good nutrient removal.
- Provides natural wildlife habitat.
- Relatively low maintenance costs.

DISADVANTAGES / LIMITATIONS:

- Requires large land area.
- Needs continuous baseflow for viable wetland.
- Regular sediment removal is critical to sustain wetlands.

MAINTENANCE REQUIREMENTS:

- Replace wetland vegetation to maintain at least 50% surface area coverage.
- Remove invasive vegetation.
- Monitor sediment accumulation and remove periodically.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**Yes**
Detention/Retention:	**Yes**

Accepts hotspot runoff: *No*

COST CONSIDERATIONS

Land Requirement:	**Med-High**
Capital Cost:	**Med**
Maintenance Burden:	
Shallow Wetland	**Med**
ED Shallow Wetland	**Med**
Pocket Wetland	**High**
Basin/Wetland	**Med**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**75%**

4.3.4.1 General Description

Stormwater wetlands (also referred to as *constructed wetlands*) are constructed shallow marsh systems that are designed to both treat urban stormwater and control runoff volumes. As stormwater runoff flows through the wetland facility, pollutant removal is achieved through settling and uptake by marsh vegetation. Wetlands can be utilized effectively for pollutant removal and also offer aesthetic value and wildlife habitat.

Constructed stormwater wetlands differ from natural wetland systems in that they are engineered facilities designed specifically for the purpose of treating stormwater runoff and typically have less biodiversity than natural wetlands both in terms of plant and animal life. However, as with natural wetlands, stormwater wetlands require a continuous base flow or a high water table to support aquatic vegetation.

There are several design variations of the stormwater wetland, each design differing in the relative amounts of shallow and deep water, and dry storage above the wetland. The variations are shown in Figure 4-19. These include the shallow wetland, the extended detention shallow wetland, basin/wetland system and pocket wetland. Below are descriptions of each design variant:

Figure 4-19. Stormwater Wetland Examples

Shallow Wetland

Extended Detention Shallow Wetland

Pocket wetland

Newly Constructed Shallow Wetland

- **Shallow Wetland** – In the shallow wetland design, most of the water quality treatment volume is in the relatively shallow high marsh or low marsh depths. The only deep portions of the shallow wetland design are the forebay at the inlet to the wetland, and the micropool at the outlet. One disadvantage of this design is that, since the pool is very shallow, a relatively large amount of land is typically needed to store the water quality volume.
- **Extended Detention (ED) Shallow Wetland** – The extended detention (ED) shallow wetland design is the same as the shallow wetland; however, part of the water quality treatment volume is provided as extended detention above the surface of the marsh and released over a period of 24 hours. This design can treat a greater volume of stormwater in a smaller space than the shallow wetland design. In the extended detention shallow wetland option, plants that can tolerate both wet and dry periods need to be specified in the ED zone.

- **Basin/Wetland System** – The basin/wetland system has two separate cells: a wet basin and a shallow marsh. The wet basin traps sediments and reduces runoff velocities prior to entry into the wetland, where stormwater flows receive additional treatment. Less land is required for a basin/wetland system than for the shallow wetland or the ED shallow wetland systems.
- **Pocket Wetland** – A pocket wetland is intended for smaller drainage areas of 5 to 10 acres and typically requires excavation down to the water table for a reliable water source to support the wetland system.

Certain types of wetlands, such as *submerged gravel wetland systems* are not recommended for general application use to meet stormwater management goals due to limited performance data. They may be applicable in special or retrofit situations where there are severe limitations on what can be implemented. Please see a further discussion of submerged gravel wetlands in Section 4.4.3.

4.3.4.2 Stormwater Management Suitability

Similar to stormwater basins, stormwater wetlands are designed to control both stormwater quantity and quality. Thus, a stormwater wetland can be used to address the minimum design standards for water quality, channel protection and flood protection for a given drainage area.

<u>Water Quality Volume (WQv)</u>
Pollutants are removed from stormwater runoff in a wetland through uptake by wetland vegetation and algae, vegetative filtering, and through gravitational settling in the slow moving marsh flow. Other pollutant removal mechanisms are also at work in a stormwater wetland, including chemical and biological decomposition, and volatilization. Section 4.3.4.3 provides median pollutant removal efficiencies that can be used for planning and design purposes.

<u>Channel Protection Volume (CPv)</u>
The storage volume above the permanent pool/water surface level in a stormwater wetland is used to provide control of the channel protection volume (CPv). This is accomplished by releasing the 1-year, 24-hour storm runoff volume over 24 hours (extended detention). It is best to do this with minimum vertical water level fluctuation, as extreme fluctuation may stress vegetation.

4.3.4.3 Pollutant Removal Capabilities

All of the stormwater wetland design variants are presumed to be able to remove 80% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the specifications provided in this manual.

The total suspended solids design pollutant removal rate of 80% is a conservative average pollutant reduction percentage for design purposes derived from sampling data, modeling and professional judgment.

For additional information and data on pollutant removal capabilities for stormwater wetlands, see the National Pollutant Removal Performance Database (2nd Edition) available at www.stormwatercenter.net and the International Stormwater Best Management Practices Database at www.bmpdatabase.org.

4.3.4.4 Application and Site Feasibility Criteria

Stormwater wetlands are generally applicable to most types of new development and redevelopment, and can be utilized in both residential and nonresidential areas. However, due to the large land requirements, wetlands may not be practical in higher density areas. The following criteria should be evaluated to ensure the suitability of a stormwater wetland for meeting stormwater management objectives on a site or development.

<u>General Feasibility</u>

- Suitable for Residential Subdivision Usage

- Suitable for High Density/Ultra Urban Areas, however, land requirements may preclude use
- Suitable for Commercial/Industrial use
- Suitable for Regional Stormwater Control

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – A minimum of 25 acres and a positive water balance is needed to maintain wetland conditions; a minimum of 5 acres for pocket wetland. The local jurisdiction may approve a smaller drainage area with an adequate water balance and anti-clogging device.
- Space Required – Approximately 3 to 5% of the tributary drainage area
- Site Slope – Wetlands are feasible on sites where the upstream slope (above the wetland) is no more than 15%.
- Minimum Head – Enough elevation drop is required, from inlet to outlet, to allow hydraulic conveyance by gravity. Generally, the minimum head for a pocket wetland is 2 to 3 feet. For all other wetlands the minimum head is 3 to 5 feet.
- Minimum Depth to Water Table – In general, no minimum separation distance to the water table is required for stormwater wetlands. In fact, water table interception may be helpful to sustain a permanent pool. However, some source water protection requirements may dictate a separation distance if there is a sensitive underlying aquifer. In such situations, an impermeable liner, or a minimum separation between 2 to 4 feet is required for portions of the wetland that will have standing water.
- Soils – Permeable soils are not well suited for a constructed stormwater wetland without a high water table. Underlying soils of hydrologic group “C” or “D” should be adequate to maintain wetland conditions. Most group “A” soils and some group “B” soils will require a liner. Evaluation of soils should be based upon an actual subsurface analysis and permeability tests.
- Karst Topography – areas with karst topography will require a liner.

4.3.4.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of a stormwater wetland facility. Stormwater wetlands that are not designed to these standards will not be approved. The local jurisdiction shall have the authority to require additional design conditions if deemed necessary.

A. LOCATION AND SITING

- Stormwater wetlands should normally have a minimum contributing drainage area of 25 acres or more. For a pocket wetland, the minimum drainage area is 5 acres. The local jurisdiction may consider allowing the use of a stormwater wetland for a smaller drainage area when water availability can be confirmed (such as from a groundwater source or areas that typically have a high water table). It is important that wetlands that serve smaller drainage areas have an adequate anti-clogging device provided for the wetland outlet.
- A continuous base flow or high water table is required to support wetland vegetation. A water balance shall be performed to demonstrate that a stormwater wetland can withstand a 30-day drought at summer evaporation rates without completely drawing down (see Chapter 3 for details).
- When determining an appropriate location for a stormwater wetland, the site designer should also take into account the location and use of other site features such as natural depressions, buffers, and undisturbed natural areas. The site designer should attempt to aesthetically “fit” the wetland into the landscape.
- Stormwater wetlands shall not be located in a stream or any other navigable waters of the United States, including natural (i.e., not constructed) wetlands. Where an appeal or variance of this policy is desired, the property owner must obtain coverage under a Section 404 permit under the Clean

- Water Act and/or an Aquatic Resource Alteration Permit (ARAP) and provide proof of such coverage with the Stormwater Management Plan. The local jurisdiction may approve the conversion of an existing degraded wetland into a stormwater wetland where appropriate for local watershed restoration efforts, and when prior approval for such a conversion is obtained from all applicable State and Federal agencies.
- If a wetland facility is not used for overbank and extreme flood protection, it shall be designed as an off-line system to bypass the higher flows rather than passing them through the wetland system.
- Each wetland or wetland system shall be placed in an easement that is recorded with the deed. The easement shall be defined at the outer edge of the safety bench, or a minimum of 15 feet from the normal water pool elevation (measured perpendicular from the pool elevation boundary) if a safety bench is not included in the wetland design. Minimum setback requirements for the easement shall be as follows unless otherwise specified by the local jurisdiction:
    - From a property line – 10 feet;
    - From a public water system well – TDEC specified distance per designated category;
    - From a private well – 100 feet; if well is downgradient from a land use that requires a Special Pollution Abatement Permit, then the minimum setback is 250 feet;
    - From a septic system tank/leach field – 50 feet.
- All utilities should be located outside of the wetland site.

B. GENERAL DESIGN

- A stormwater wetland shall consist of the following elements, design in accordance with the specifications provided in this section.
    - Shallow marsh areas of varying depths with wetland vegetation;
    - Permanent micropool;
    - Overlying zone in which runoff control volumes are stored if the wetland will be used for storage of the CPv and the locally regulated peak discharge.
    - Emergency spillway;
    - Maintenance access;
    - Safety bench;
    - Sediment forebay at each wetland inlet (unless the inlet provides less than 10% of the total inflow to the wetland);
    - Wetland buffer (this is not the same as a regulatory vegetated buffer – see section I-Landscaping for more information); and
    - Appropriate wetland vegetation and native landscaping.
    - Basin/wetland systems also include stormwater basin facilities that must meet all of the design parameters in Section 4.3.1 for basin design.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

In general, wetland designs are unique for each site and application. However, there are number of geometric ratios and limiting depths for the design of a stormwater wetland that shall be observed for adequate pollutant removal, ease of maintenance, and improved safety. Table 4-8 provides the recommended physical specifications and geometry for the various stormwater wetland design variants.

Table 4-8. Recommended Design Criteria for Stormwater Wetlands

(Source: Modified from Massachusetts DEP, 1997; Schueler, 1992)

Design Criteria	Shallow Wetland	ED Shallow Wetland	Basin/ Wetland	Pocket Wetland
Length to Width Ratio (minimum)	2:1	2:1	2:1	2:1
Extended Detention (ED)	No	Yes	Optional	Optional
Allocation of WQv Volume (pool/marsh/ED) in %	25/75/0	25/25/50	70/30/0 (includes basin volume)	25/75/0
Allocation of Surface Area (deepwater/low marsh/high marsh/semi-wet)[1] in %	20/35/40/5	10/35/45/10	45/25/25/5 (includes basin surface area)	10/45/40/5
Forebay	Required	Required	Required	See section D below
Micropool	Required	Required	Required	Required
Outlet Configuration	Reverse-slope pipe or hooded broad-crested weir	Reverse-slope pipe or hooded broad-crested weir	Reverse-slope pipe or hooded broad-crested weir	Hooded broad-crested weir

1 – Depth Considerations:
Deepwater: 1.5 to 6 feet below normal pool elevation
Low marsh: 6 to 18 inches below normal pool elevation
High marsh: 6 inches or less below normal pool elevation
Semi-wet zone: Above normal pool elevation

- The stormwater wetland shall be designed with the recommended proportion of "depth zones." Each of the four wetland design variants has depth zone allocations which are given as a percentage of the stormwater wetland surface area. Target allocations are found in Table 4-8. The four basic depth zones are:

  Deepwater zone
  From 1.5 to 6 feet deep. Includes the outlet micropool and deepwater channels through the wetland facility. This zone supports little emergent wetland vegetation, but may support submerged or floating vegetation.

  Low marsh zone
  From 6 to 18 inches below the normal permanent pool or water surface elevation. This zone is suitable for the growth of several emergent wetland plant species.

  High marsh zone
  From 6 inches below the pool to the normal pool elevation. This zone will support a greater density and diversity of wetland species than the low marsh zone. The high marsh zone should have a higher surface area to volume ratio than the low marsh zone.

  Semi-wet zone
  Those areas above the permanent pool that are inundated during larger storm events. This zone supports a number of species that can survive flooding.

- A dry weather flow path shall be provided from inflow to outlet across the stormwater wetland. The path shall have a minimum length to width ratio of 2:1. Ideally, the path length to width ratio should be greater than 3:1. This path may be achieved by constructing internal dikes or berms, using marsh plantings, and/or by using multiple cells. Finger dikes are commonly used in surface flow systems to create serpentine configurations and prevent short-circuiting. Microtopography (contours along the bottom of a wetland or marsh that provide a variety of conditions for different species needs and increases the surface area to volume ratio) is encouraged to enhance wetland diversity.

- A micropool having a depth no greater than 4 to 6 feet shall be included in the design at the outlet to prevent outlet clogging and resuspension of sediments, and to mitigate thermal effects.
- Maximum depth of any permanent pool areas shall not exceed 6 feet.
- The volume that is handled through extended detention shall not comprise more than 50% of the total WQv, and its maximum water surface elevation shall not extend more than 3 feet above the normal pool. Storage of CPv and the locally regulated peak discharge can be provided above the maximum WQv elevation within the wetland.
- The perimeter of all deep pool areas (4 feet or greater in depth) shall be surrounded by safety and aquatic benches similar to those for stormwater basins (see subsection 4.3.1).
- The contours of the wetland shall be irregular to provide a more natural landscaping effect.

D. PRETREATMENT / INLETS

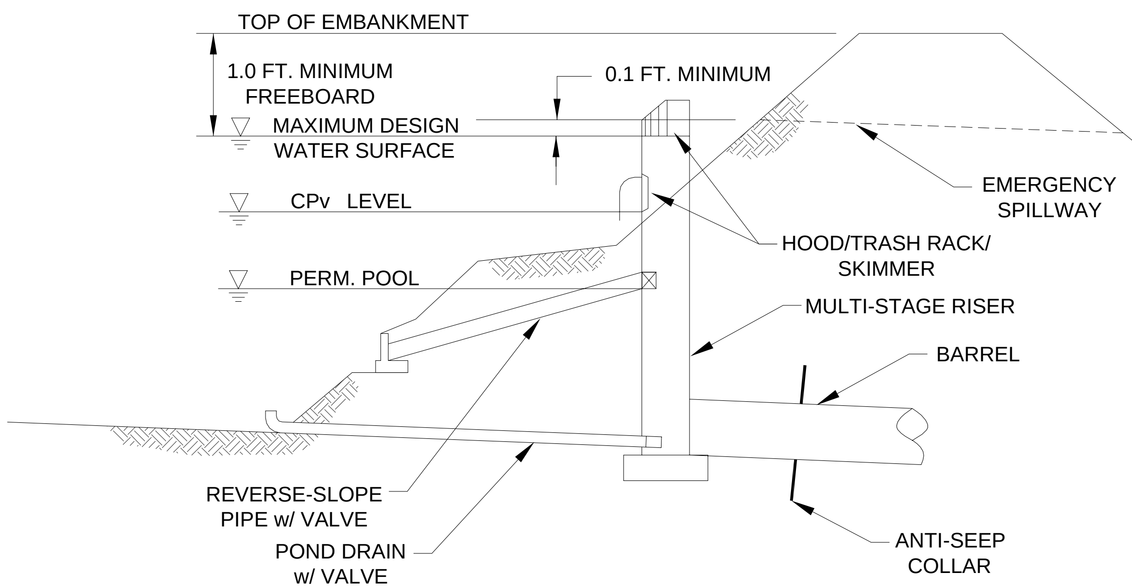
- Sediment regulation and removal is critical to sustain stormwater wetlands. A wetland facility shall have a sediment forebay or equivalent upstream pretreatment. In some cases, a pocket wetland design may not allow construction of a sediment forebay because of space limitations on small sites. In this case, a smaller “cattail” forebay is recommended to capture trash, debris and oil.
- A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to dispersal into the wetland. The forebay shall consist of a separate cell, formed by an acceptable barrier. A forebay shall be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the wetland facility.
- The forebay shall be sized to contain 0.1 inches per impervious acre (363 ft^3) of contributing drainage and shall be no more than 4 to 6 feet deep. The pretreatment storage volume is part of the total WQv design requirement and may be subtracted from the WQv for wetland storage sizing.
- A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.
- Inflow channels shall be stabilized with flared riprap aprons, or the equivalent. Inlet pipes to the basin can be partially submerged. Exit velocities from the forebay to the wetland shall be nonerosive.

E. OUTLET STRUCTURES

- Flow control from a stormwater wetland is typically accomplished with the use of a concrete or corrugated metal riser and barrel. The riser is a vertical pipe or inlet structure that is attached to the base of the micropool with a watertight connection. The outlet barrel is a horizontal pipe attached to the riser that conveys flow under the embankment (see Figure 4-20). The riser shall be located within the embankment for maintenance access, safety and aesthetics.
- A number of outlets at varying depths in the riser provide internal flow control for routing of WQv, CPv, and the locally regulated peak discharge. The number of orifices can vary and is usually a function of the wetland design.

  For shallow and pocket wetlands, the riser configuration is typically comprised of a channel protection outlet (usually an orifice) and overbank flood protection outlet (often a slot or weir). The channel protection orifice is sized to release the channel protection storage volume over a 24-hour period. Since the water quality volume is fully contained in the permanent pool, no orifice sizing is necessary for this volume. As runoff from a water quality event enters the wet basin, it simply displaces that same volume through the channel protection orifice. Thus an off-line shallow or pocket wetland providing only water quality treatment can use a simple overflow weir as the outlet structure.

Figure 4-20. Typical Wetland Facility Outlet Structure



In the case of an extended detention (ED) shallow wetland; there is generally a need for an additional outlet (usually an orifice) that is sized to pass the extended detention water quality volume that is surcharged on top of the permanent pool. Flow will first pass through this orifice, which is sized to release the water quality ED volume in 24 hours. The preferred design is a reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool to prevent floatables from clogging the pipe and to avoid discharging warmer water at the surface of the basin. The next outlet is sized for the release of the channel protection storage volume. The outlet (often an orifice) invert is located at the maximum elevation associated with the extended detention water quality volume and is sized to release the channel protection storage volume over a 24-hour period.

Alternative hydraulic control methods to an orifice can be used and include the use of a broad-crested rectangular, V-notch, proportional weir, or an outlet pipe protected by a hood that extends at least 12 inches below the normal pool.

- The water quality outlet (if design is for an ED shallow wetland) and channel protection outlet shall be fitted with adjustable gate valves or other mechanism that can be used to adjust detention time.
- Higher flows (locally regulated peak discharge) pass through openings or slots protected by trash racks that are located further up on the riser.
- After entering the riser, flow is conveyed through the barrel and is discharged downstream. Anti-seep collars shall be installed on the outlet barrel to reduce the potential for pipe failure.
- Riprap, plunge pools or pads, or other energy dissipators shall be placed at the outlet of the barrel to prevent scouring and erosion. If a wetland facility discharges to a stream that has dry weather flow at any time during the year, care should be taken to minimize land disturbance along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance. See Chapter 7 (Construction Site Stormwater Management) and Chapter 6 (Vegetated Buffers) for more guidance on outlet designs and rules and regulations for disturbances in a vegetated buffer.

- The wetland facility shall have a bottom drain pipe located in the micropool with an adjustable valve that can completely or partially drain the wetland within 24 hours.
- The wetland drain shall be sized one pipe size greater than the calculated design diameter. The drain valve is typically a handwheel activated knife or gate valve. Valve controls shall be located inside of the riser at a point where they (a) will not normally be inundated and (b) can be operated in a safe manner.

See the design procedures in subsection 4.3.4.6 as well as Chapter 3 for additional information and specifications on basin routing and outlet operations.

F. EMERGENCY SPILLWAY

- An emergency spillway shall be included per regulations of the local jurisdiction.

G. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right of way or easement shall be provided from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.
- The maintenance access shall extend to the forebay, safety bench, riser, and outlet, and, to the extent feasible, be designed to allow vehicles to turn around.
- Access to the riser shall be provided by lockable manhole covers, and manhole steps within easy reach of valves and other controls.

H. SAFETY FEATURES

- All embankments and spillways shall be designed to the requirements set by TDEC's Safe Dams Act of 1973.
- Fencing of wetlands is not generally desirable, but may be required by the local jurisdiction. A preferred method is to manage the contours of deep pool areas through the inclusion of a safety bench (see above) to eliminate dropoffs and reduce the potential for accidental drowning. In addition, the safety bench may be landscaped to deter access to the pool.
- All outlet structures shall be designed so as not to permit access by children.

I. LANDSCAPING

- A landscaping plan shall be developed that indicates the methods used to establish and maintain wetland coverage. Minimum considerations of the plan include: delineation of landscaping zones, selection of corresponding plant species, planting plan, sequence for preparing wetland bed (including soil amendments, if needed) and sources of plant material. More information on wetland plants can be found at the following websites:
  - http://wetlands.fws.gov/
  - http://www.npwrc.usgs.gov/resource/plants/floraso/species.htm
  - http://www.tva.gov/river/landandshore/stabilization/plantsearch.htm
- Landscaping zones include low marsh, high marsh, and semi-wet zones. The low marsh zone ranges from 6 to 18 inches below the normal pool. This zone is suitable for the growth of several emergent plant species. The high marsh zone ranges from 6 inches below the pool up to the normal pool. This zone will support greater density and diversity of emergent wetland plant species. The high marsh zone should have a higher surface area to volume ratio than the low marsh zone. The semi-wet zone refers to those areas above the permanent pool that are inundated on an infrequent basis and can be expected to support wetland plants.

- The landscaping plan should provide elements that promote greater wildlife and waterfowl use within the wetland and buffers.
- Woody vegetation shall not be planted on the embankment or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.
- Vegetated buffers, as defined and described in Chapter 6 of this manual, are not required for wetlands that are constructed for the purpose of stormwater quality or quantity control. However, it should be noted that vegetated buffers can be utilized for water quality treatment and can result in a volume reduction that reduces the WQv. The criteria for the vegetated buffer reduction are presented in Chapter 5 of this manual.
- Existing trees should be preserved in the wetland area during construction, or should be replanted. It is desirable to locate forest conservation areas adjacent to wetlands. To discourage resident waterfowl populations, the wetland buffer can be planted with trees, shrubs and native ground covers.
- The soils in planting areas within and surrounding a wetland are often severely compacted during the construction process to ensure stability. The density of these compacted soils is so great that it effectively prevents root penetration and therefore may lead to premature mortality or loss of vigor. Consequently, it is advisable to excavate large and deep holes around the proposed planting sites and backfill these with <u>uncompacted</u> topsoil.
- Native species of fish can be stocked in the permanent pool to aid in mosquito prevention The use of non-native fish species in a stormwater facility is strongly discouraged due to the possibility that the fish will enter downstream receiving waters.
- A fountain or aerator may be used for oxygenation of water in the permanent pool and to aid in mosquito breeding prevention.

<u>J. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES</u>

There are a number of additional site specific design criteria and issues (listed below) that must be considered in the design of wetlands.

<u>Physiographic Factors - Local terrain design constraints</u>

- <u>Low Relief</u> – Providing wetland drain can be problematic
- <u>Karst</u> – Requires poly or clay liner to sustain a permanent pool of water and protect aquifers; limits on ponding depth; geotechnical tests may be required. Stormwater wetlands are the preferred BMP over basins in the karst areas.

<u>Soils</u>

- Hydrologic group “A” soils and some group “B” soils may require liner (not relevant for pocket wetland)

<u>Special Watershed Considerations</u>

- <u>Wellhead Protection</u> – The potential for groundwater contamination (in required wellhead protection areas) shall be reduced through pretreatment of runoff, and installation of a liner for type “A” and “B” soils; Pretreat hotspots; 2 to 4 foot separation distance from water table.

4.3.4.6 Design Procedures

<u>Step 1. Compute runoff control volumes</u>

> Calculate the WQv, CPv, and the locally regulated peak discharges, in accordance with the guidance presented in Chapter 3.

Step 2. Determine if the development site and conditions are appropriate for the use of a stormwater wetland

Consider the Application and Site Feasibility Criteria in subsections 4.3.4.4 and 4.3.4.5-A (Location and Siting).

Step 3. Confirm design criteria and applicability

Consider any special site-specific design conditions/criteria from subsection 4.3.4.5-J (Additional Site-Specific Design Criteria and Issues).

Check with the local jurisdiction, TDEC, or other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 4. Determine pretreatment volume

A sediment forebay is provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the basin. The forebay shall be sized to contain 0.1 inches per impervious acre (363 ft^3) of contributing drainage and shall be 4 to 6 feet deep. The forebay storage volume counts toward the total WQv requirement and may be subtracted from the WQv for subsequent calculations.

Step 5. Allocate the WQv volume among marsh, micropool, and ED volumes

Use recommended criteria from Table 4-8 in Section 4.3.4.5.

Step 6. Determine wetland location and preliminary geometry, including distribution of wetland depth zones

This step involves initially laying out the wetland design and determining the distribution of wetland surface area among the various depth zones (high marsh, low marsh, and deepwater). Set WQv permanent pool elevation (and WQv-ED elevation for ED shallow wetland) based on volumes calculated earlier.

Step 7. Compute extended detention orifice release rate(s) and size(s), and establish CPv elevation

Shallow Wetland and Pocket Wetland: The CPv elevation is determined from the stage-storage relationship and the orifice is then sized to release the channel protection storage volume over a 24-hour period, centroid to centroid. The channel protection orifice should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool is a recommended design. Orifice diameters less than three inches must employ internal orifice protection (i.e., an over-perforated vertical stand pipe with ½-inch orifices or slots that are protected by wirecloth and a stone filtering jacket).

ED Shallow Wetland: Based on the elevations established in Step 6 for the extended detention portion of the water quality volume, the water quality orifice is sized to release this extended detention volume in 24 hours. The water quality orifice be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged one foot below the elevation of the permanent pool, is a recommended design. Orifice diameters less than three inches must employ internal orifice protection (i.e., an over-perforated vertical stand pipe with ½-inch orifices or slots that are protected by wirecloth and a stone filtering jacket). The CPv elevation is then determined from the stage-storage relationship. The invert of the channel protection orifice is located at the water quality extended detention elevation, and the orifice is sized to release the channel protection storage volume over a 24-hour period, centroid to centroid.

Step 8. Calculate the locally regulated peak discharge release rates and water surface elevations

Set up a stage-storage-discharge relationship for the control structure for the extended detention orifice(s) and the locally specified storms.

Step 9. Design embankment(s) and spillway(s)

An emergency spillway shall be included per regulations of the local jurisdiction.

Step 10. Investigate potential basin/wetland hazard classification

The design and construction of stormwater management facilities are required to follow the latest version of the TDEC Rules and Regulations Application to the Safe Dams Act of 1973.

Step 11. Design inlets, sediment forebay(s), outlet structures, maintenance access, and safety features.

See subsection 4.3.4.5-D through H for more details.

Step 12. Design landscape plan

A landscape plan for a stormwater wetland and its buffer shall be prepared to indicate how aquatic and terrestrial areas will be stabilized and established with vegetation. See subsection 4.3.4.5-I (Landscaping) for more details.

This space intentionally left blank

4.3.4.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.4.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of stormwater wetlands as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local jurisdiction has the authority to impose additional maintenance requirements where deemed necessary. This page provides guidance on maintenance activities that are typically required for stormwater wetlands, along with a suggested frequency for each activity. Individual wetlands may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e.., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the basin in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• After several storm events or an extreme storm event, inspect for: bank stability; signs of erosion; vegetation growth; drainage system function; and structural damage.	As needed
• Inspect for: invasive vegetation; trash and debris; clogging of the inlet/outlet structures and any pilot or low flow channels; excessive erosion; sediment accumulation in the basin, forebay and inlet/outlet structures; tree growth on dam or embankment; the presence of burrowing animals; standing water where there should be none; vigor and density of the grass turf on the basin side slopes and floor; differential settlement; cracking; leakage; and slope stability.	Semi-annually
• Inspect the inlet/outlet structures, pipes, sediment forebays, and upstream, downstream, and pilot channels are free of debris and are operational. • Check for signs of unhealthy or overpopulation of plants and/or fish (if utilized). • Note signs of pollution, such as oil sheens, discolored water, or unpleasant odors. • Check sediment marker(s) for sediment accumulation in the facility and forebay. • Check for proper operation of control gates, valves or other mechanical devices. • Note changes to the wetland or contributing drainage area as such changes may affect wetland performance.	Annually
Maintenance Activities	**Suggested Schedule**
• Replace wetland vegetation to maintain at least 50% surface area coverage in wetland plants after the second growing season.	One-time
• Clean and remove debris from inlet and outlet structures. Mow side slopes (embankment) and maintenance access. Periodic mowing is only required along maintenance rights-of-way and the embankment. The wetland buffer surrounding the wetland can be managed as a meadow (mowing every other year) or forest.	Frequently (3 to 4 times per year)
• Supplement wetland plants if a significant portion have not established (at least 50% of the surface area). Remove unhealthy, invasive or nuisance plant species and replant with appropriate species if necessary. Harvest plant species if vegetation becomes too thick causing flow backup and flooding, or an overabundance of undesirable wildlife.	Annually (if needed)
• Repair damage to basin, outlet structures, embankments, control gates, valves, or other mechanical devices; repair undercut or eroded areas. Remove litter, debris, pollutants as appropriate.	As Needed
• Remove sediment from the forebay. Sediments excavated from stormwater wetlands that receive treated runoff from hotspot land uses are not considered toxic or hazardous material and can be safely disposed of by either land application or landfilling.	As needed (typically every 5 to 7 years)
• Monitor sediment accumulations, and remove sediment when the volume in the wetland, forebay, or micropool has become reduced significantly or the wetland area is not providing a healthy habitat for vegetation and fish (if used). Discharges of turbid or untreated stormwater from the wetland may be considered an illegal discharge, as per the local stormwater management regulations. Care should be exercised during wetland drawdowns to prevent downstream discharge of sediments, anoxic water, or high flows with erosive velocities. The local jurisdiction should be notified before draining a stormwater wetland.	As needed (typically every 20 to 50 years)

The local jurisdiction encourages the use of the inspection checklist that is presented on the next page to guide the property owner in the inspection and maintenance of stormwater wetlands. The local jurisdiction can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the wetland. Questions regarding stormwater facility inspection and maintenance should be referred to the local jurisdiction.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
STORMWATER WETLAND INSPECTION CHECKLIST

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: __________ Time: ____________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Embankment and Emergency Spillway		
Healthy vegetation?		
Erosion on embankment?		
Animal burrows in embankment?		
Cracking, sliding, bulging of dam?		
Blocked or malfunctioning drains?		
Leaks or seeps on embankment?		
Obstructions of spillway(s)?		
Erosion in/around emergency spillway?		
Other (describe)?		
Inlet/Outlet Structures and Channels		
Clear of debris and functional?		
Trash rack clear of debris and functional?		
Sediment accumulation?		
Condition of concrete/masonry?		
Metal pipes in good condition?		
Control valve operation?		
Drain valve operation?		
Outfall channels function, not eroding?		
Other (describe)?		
Sediment Forebays		
Evidence of sediment accumulation?		
Permanent Pool Areas (if applicable)		
Undesirable vegetation growth?		
Visible pollution?		
Shoreline erosion?		
Erosion at outfalls into wetland?		
Headwalls and endwalls in good condition?		
Encroachment by other activities?		
Evidence of sediment accumulation?		
Wetland Vegetation Areas		
Vegetation adequate?		
Undesirable vegetation growth?		
Excessive sedimentation?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:______________________________ Inspector Name (printed)________________________

4.3.4.8 Example Schematics

Figure 4-21. Schematic of a Shallow Wetland

(Source: Adapted from Atlanta Regional Council, 2000)

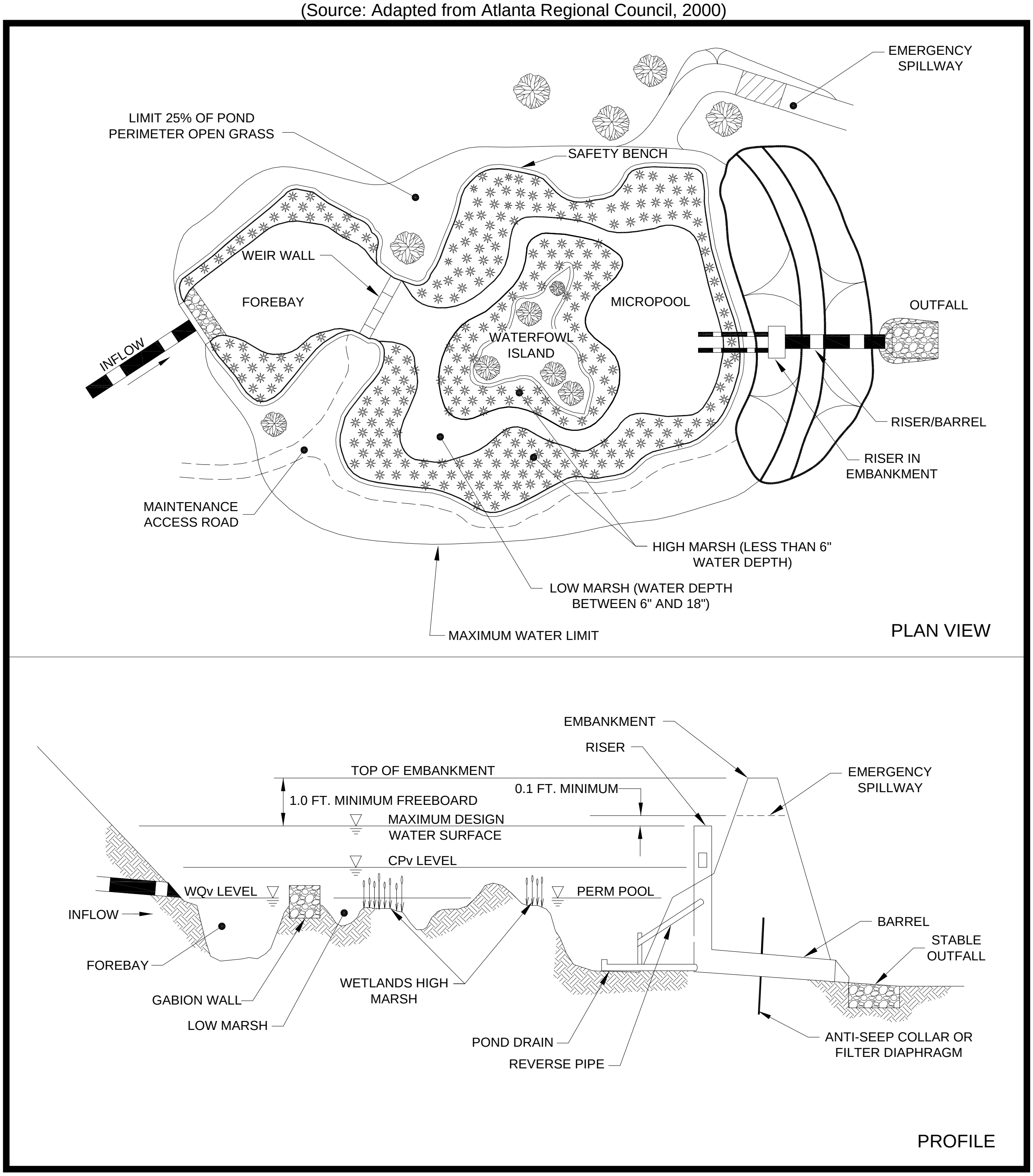


Figure 4-22. Schematic of an Extended Detention Shallow Wetland
(Source: Adapted from Atlanta Regional Council, 2000)

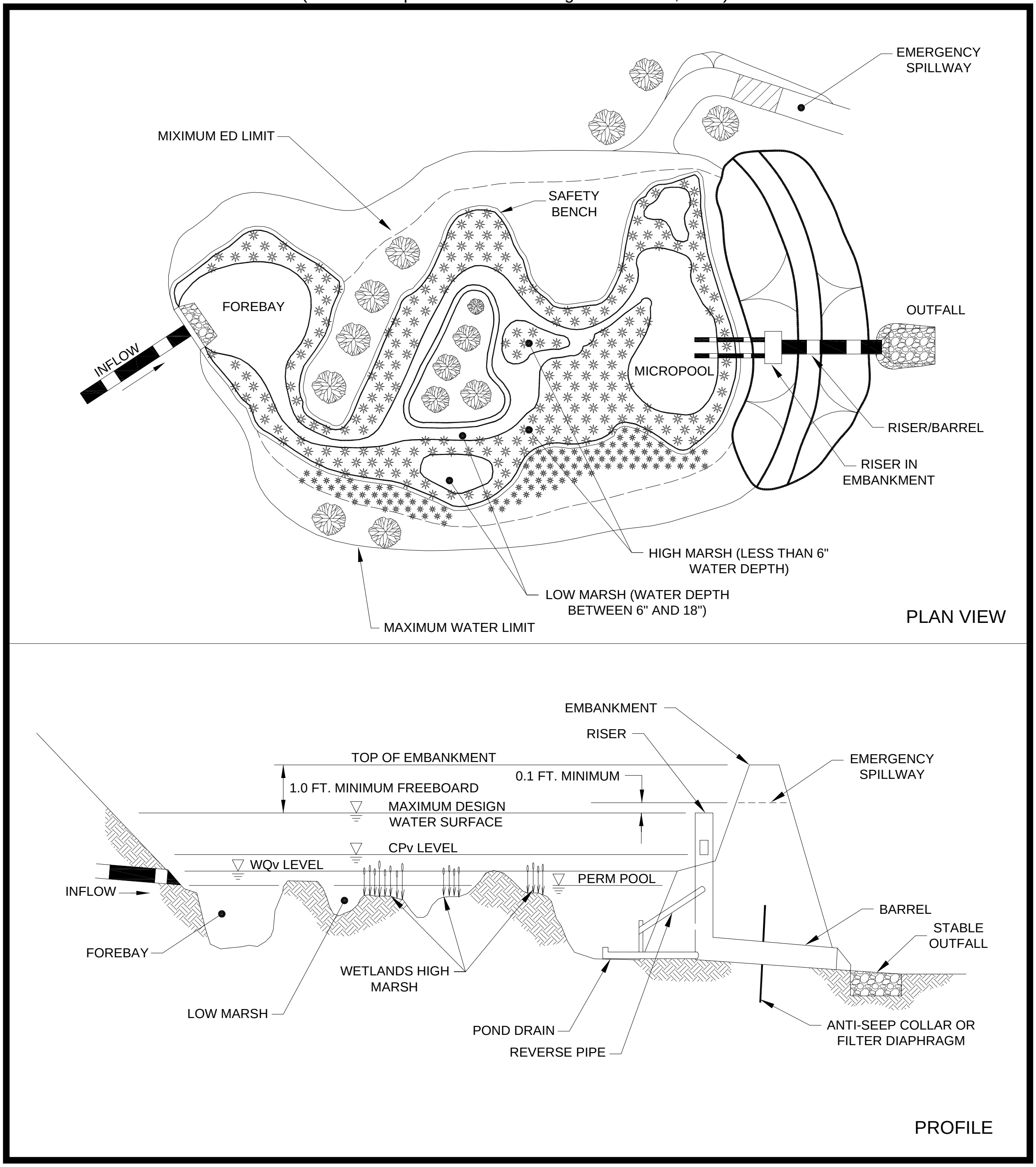


Figure 4-23. Schematic of a Basin/Wetland System

(Source: Adapted from Atlanta Regional Council, 2000)

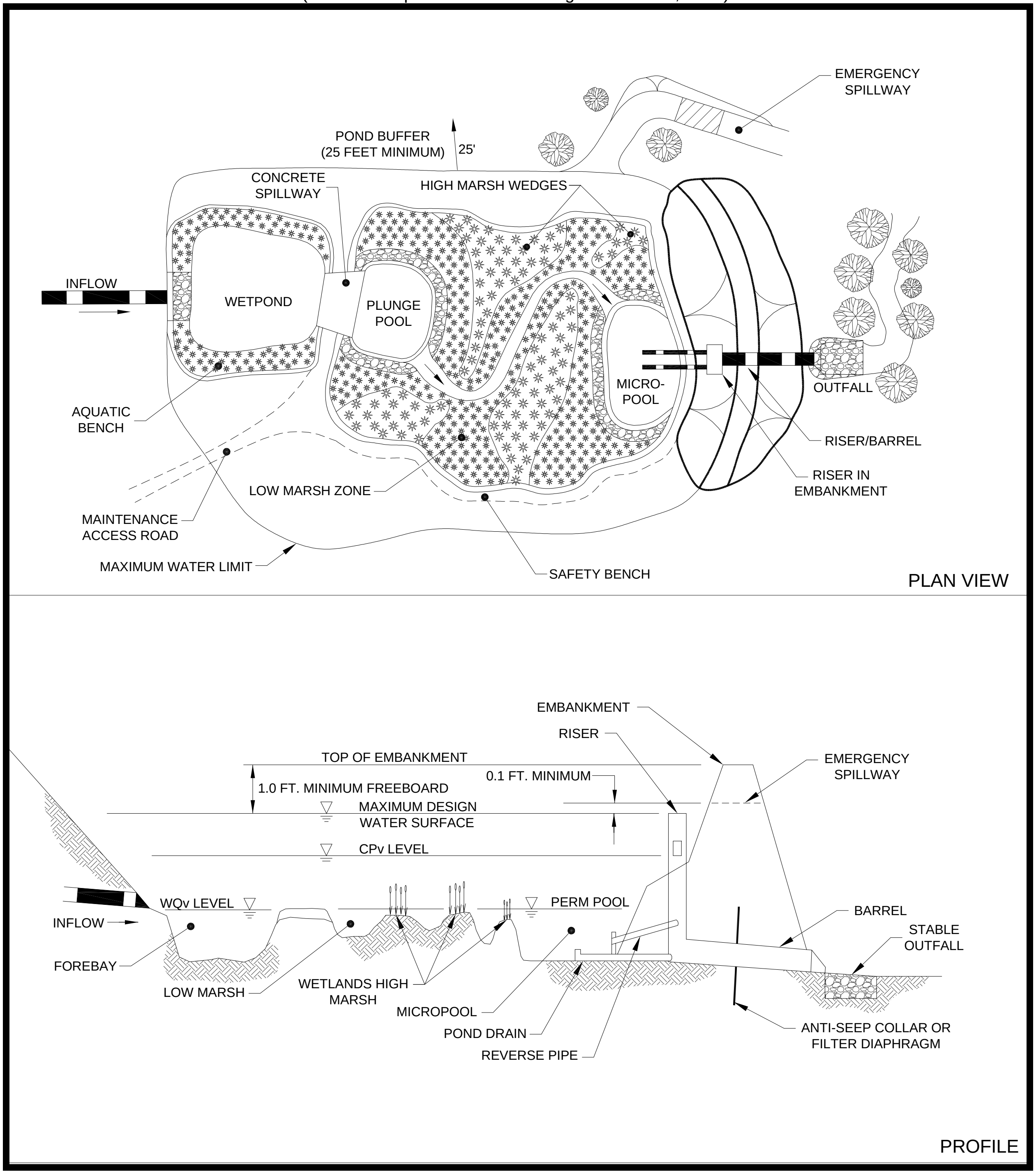
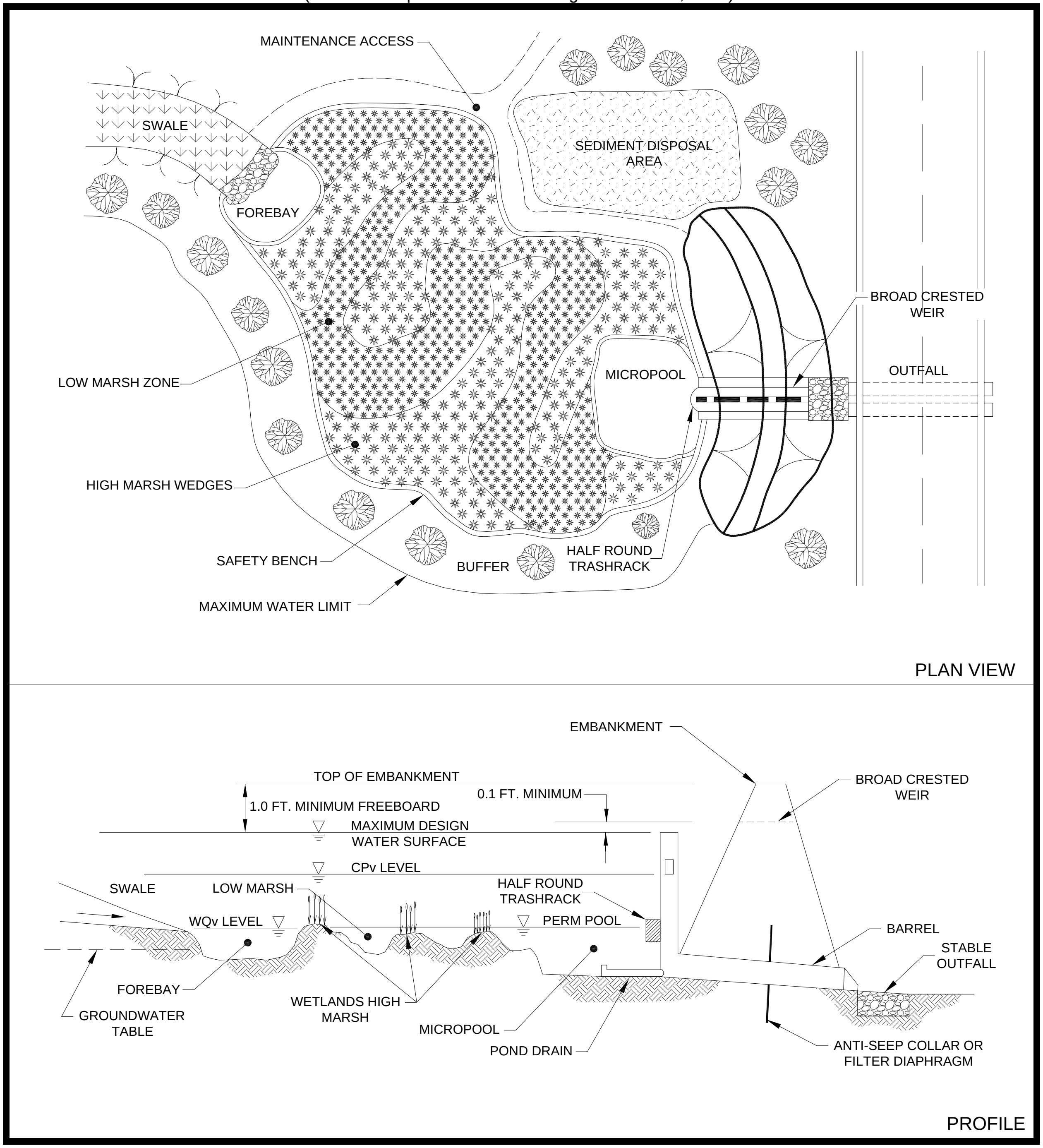


Figure 4-24. Schematic of a Pocket Wetland
(Source: Adapted from Atlanta Regional Council, 2000)



4.3.4.9 Design Form

Use of the following design procedure forms are recommended when designing a stormwater wetland. Proper use and completion of the form may allow a faster review of the Water Quality Management Plan by the local jurisdiction.

Design Procedure Form: Stormwater Wetlands

PRELIMINARY HYDROLOGIC CALCULATIONS

1a. Compute WQv volume requirements
Compute Runoff Coefficient, Rv — Rv = ________
Compute WQv — WQv = ________ acre-ft

1b. Compute CPv — CPv = ________ acre-ft

STORMWATER WETLAND DESIGN

2. Is the use of a stormwater wetland appropriate? — ***See subsections 4.3.4.4 and 4.3.4.5 - A***

3. Confirm design criteria and applicability. — ***See subsection 4.3.4.5 - J***

4. Pretreatment Volume (Forebay)
V_{pre} =(I)(.1")(1'/12") — V_{pre} = ________ acre-ft

5. Allocation of pool, Marsh, and ED Volumes

Shallow Wetland
Vol_{pool}= 0.2(WQv)-Vol_{pre} — Vol_{pool}= ________ acre-ft
Vol_{marsh}= 0.7(WQv)-Vol_{pre} — Vol_{marsh}= ________ acre-ft

Shallow ED Wetland
Vol_{pool}= 0.1(WQv)-Vol_{pre} — Vol_{pool}= ________ acre-ft
Vol_{marsh}= 0.3(WQv)-Vol_{pre} — Vol_{marsh}= ________ acre-ft
Vol_{ED}= 0.5(WQv)-Vol_{pre} — Vol_{ED}= ________ acre-ft

Pocket Wetland
Vol_{pool}= 0.1(WQv)-Vol_{pre} — Vol_{pool}= ________ acre-ft
Vol_{marsh}= 0.8(WQv)-Vol_{pre} — Vol_{marsh}= ________ acre-ft

6. Allocation of Surface Area

Pool/Deepwater Wetland Zone (1.5-6 feet deep) — $Area_{water}$= ________ acres, %= ________
Low Marsh Wetland Zone (6-18 inches deep) — $Area_{low}$= ________ acres, %= ________
High Marsh Wetland Zone (0-6 inches deep) — $Area_{high}$= ________ acres, %= ________
Semi-Wet Wetland Zone (above pool depth) — $Area_{semi}$= ________ acres, %= ________
100.00%

7. Conduct grading and determine storage available for marsh zones (and ED if applicable), and compute orifice size for peak flow control per local regulations

Prepare an elevation-storage table and curve using the average area method for computing volumes. Size orifices by routing.

Elevation MSL	Area ft^2	Ave. Area ft^2	Depth ft	Volume ft^3	Cumulative Volume ft^3	Cumulative Volume acre-ft	Volume above Permanent Pool acre-ft

8. Check inlet condition
Check outlet conditions

Use culverty design guidance from local municipality

9. Size emergency spillway using the local municipality peak discharge and set top of embankment elevation and emergency spillway elevation based on $WSEL_{peak}$

Q_{ES}=Qp_{peak} ________ cfs
$WSEL_{peak}$= ________ ft
El_{embank}= ________ ft
El_{ES}= ________ ft

10. Verify peak flow control, water quality drawdown time and channel protection detention time

4.3.4.10 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2000.

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center, Accessed July 2005. www.stormwatercenter.net

City of Nashville, Tennessee. *Metropolitan Nashville and Davidson County Stormwater Management Manual, Volume 4 Best Management Practices.* 2006.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

Massachusetts Department of Environmental Protection and the Massachusetts Office of Coastal Zone Management. *Stormwater Management -- Volume One: Stormwater Policy Handbook, and Volume Two: Stormwater Technical Handbook*, 1997.

Schueler, T.J. *Design of Stormwater Wetland Systems*, Metrolpolitan Washington Council of Governments, Washington, D.C., April, 1992.

4.3.4.11 Suggested Reading

Adams, L., Dove L.E., D.L. Leedy, and T. Franklin. *Urban Wetlands for Stormwater Control and Wildlife Enhancement – Analysis and Evaluation.* Urban Wildlife Research Center, Columbia, Maryland, 1983.

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

US EPA. *Storm Water Technology Fact Sheet: Storm Water Wetlands.* EPA 832-F-99-025, Office of Water, 1999.

Faulkner, S. and C. Richardson. *Physical and Chemical Characteristics of Freshwater Wetland Soils.* Constructed Wetlands for Wastewater Treatment, ed. D. Hammer, Lewis Publishers, 831 pp, 1991.

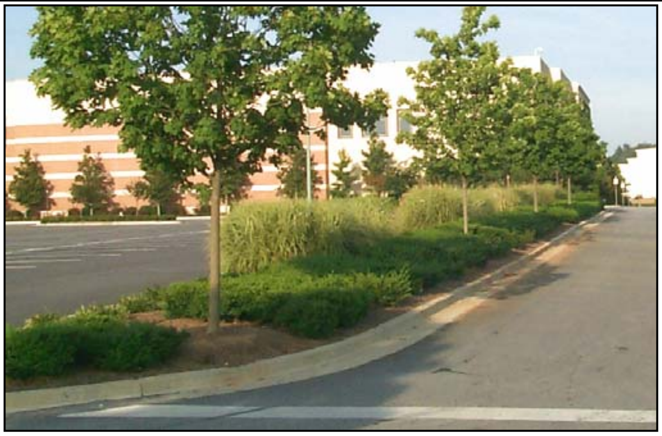
Guntenspergen, G.R., F. Stearns, and J. A. Kadlec. *Wetland Vegetation.* Constructed Wetlands for Wastewater Treatment, ed. D. A. Hammer, Lewis Publishers, 1991.

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

4.3.5 Bioretention Areas

**General Application
Water Quality BMP**



Description: Shallow stormwater basin or landscaped area that utilizes engineered soils and vegetation to capture and treat runoff.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Maximum contributing drainage area of 5 acres.
- Often located in "landscaping islands."
- Treatment area consists of grass filter, sand bed, ponding area, organic/mulch layer, planting soil, and vegetation.
- Typically requires 5 feet of elevation difference from inflow to outflow.
- Planting soils must meet specified criteria; no restrictions on surrounding soils.
- Use of native plants is recommended.

ADVANTAGES / BENEFITS:

- Applicable to small drainage areas.
- Good for highly impervious areas, particularly parking lots.
- Good retrofit capability.
- Relatively low maintenance requirements.
- Can be planned as an aesthetic feature.

DISADVANTAGES / LIMITATIONS:

- Requires extensive landscaping.
- Not recommended for areas with steep slopes.

MAINTENANCE REQUIREMENTS:

- Inspect and repair/replace treatment area components.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	✷
Detention/Retention:	**Yes**

✷ in certain situations

Accepts hotspot runoff: *Yes*

COST CONSIDERATIONS

Land Requirement:	**Med**
Capital Cost:	**Med**
Maintenance Burden:	**Low**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**85%**

4.3.5.1 General Description

Bioretention areas (also referred to as *bioretention filters* or *rain gardens*) are structural stormwater controls that capture and temporarily store the water quality volume (WQv) using soils and vegetation in shallow basins or landscaped areas to remove pollutants from stormwater runoff.

Bioretention areas are engineered facilities in which runoff is conveyed as sheet flow to the “treatment area,” which consists of a grass buffer strip, ponding area, organic or mulch layer, planting soil, and vegetation. An optional sand bed can also be included in the design to provide aeration and drainage of the planting soil. The filtered runoff is typically collected and returned to the conveyance system, though it can also permeate into the surrounding soil in areas with porous soils.

There are numerous design applications, both on- and off-line, for bioretention areas. These include use on single-family residential lots (*rain gardens*), as off-line facilities adjacent to parking lots, along road drainage swales, within larger landscaped pervious areas, and as landscaped islands in impervious or high-density environments. Figures 4-25 and 4-26 illustrate a number of examples of bioretention facilities in both photographs and drawings.

Figure 4-25. Bioretention Area Examples

Single-Family Residential “Rain Garden”

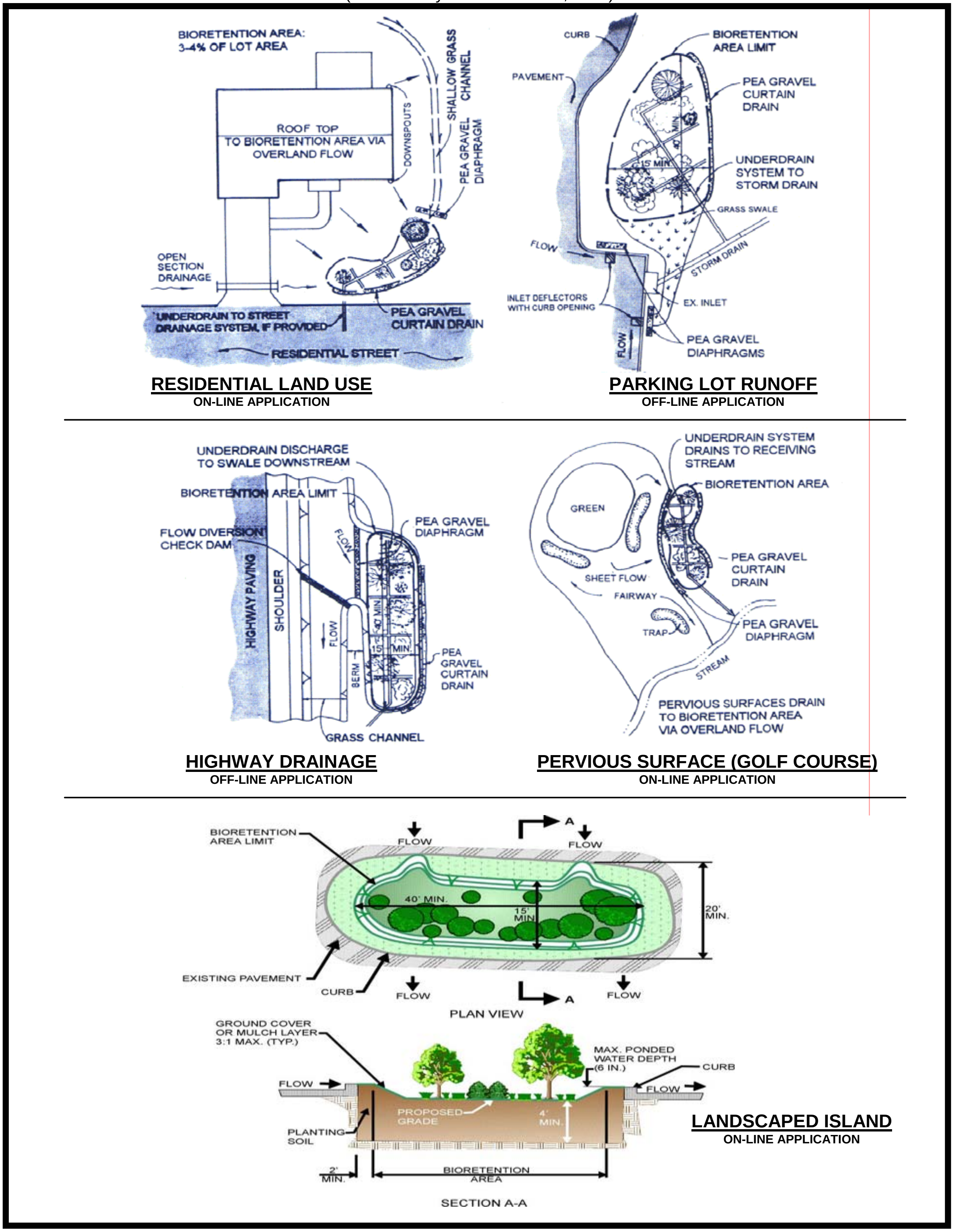
Landscaped Island

Newly Constructed Bioretention Area

Newly Planted Bioretention Area after Storm Event

Figure 4-26. Bioretention Area Applications

(Source: Claytor and Schueler, 1996)



4.3.5.2 Stormwater Management Suitability

Bioretention areas are designed primarily for stormwater quality and can provide limited runoff quantity control, primarily for smaller storm events. These facilities may sometimes be used to partially or completely meet channel protection volume (CPv) requirements on smaller sites. However, bioretention areas will typically need to be used in conjunction with other structural BMPs to provide channel protection as well as protection of the locally regulated peak discharge. It is important to ensure that a bioretention area safely bypasses higher flows.

<u>Water Quality (WQv)</u>
Bioretention is an excellent stormwater treatment practice due to the variety of pollutant removal mechanisms. Each of the components of the bioretention area is designed to perform a specific function (see Figure 4-27). The *grass filter strip (or grass channel)* reduces incoming runoff velocity and filters particulates from the runoff. The *ponding area* provides for temporary storage of stormwater runoff prior to its evaporation, infiltration, or uptake and provides additional settling capacity. The *organic or mulch layer* provides filtration as well as an environment conducive to the growth of microorganisms that degrade hydrocarbons and organic material. The *planting soil* in the bioretention facility acts as a filtration system, and clay in the soil provides adsorption sites for heavy metals, nutrients and other pollutants. Both *woody and herbaceous plants* in the ponding area provide vegetative uptake of runoff and pollutants and also serve to stabilize the surrounding soils. Finally, an *underdrain system* provides for positive drainage and aerobic conditions in the planting soil.

Section 4.3.5.3 provides median pollutant removal efficiencies that can be used for planning and design purposes.

<u>Channel Protection (CPv)</u>
For smaller sites, a bioretention area may be designed to capture the entire channel protection volume (CPv) in either an off or on-line configuration. Given that a bioretention facility must be designed to completely drain over 48 hours, the requirement of extended detention of the 1-year, 24-hour storm runoff volume will be met. For larger sites or where only the WQv is diverted to the bioretention facility, another structural BMP must be used to provide CPv extended detention.

4.3.5.3 Pollutant Removal Capabilities

Bioretention areas are presumed to be able to remove 85% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. Undersized or poorly designed bioretention areas can reduce TSS removal performance.

The total suspended solids design pollutant removal rate of 85% is a conservative average pollutant reduction percentage for design purposes derived from sampling data, modeling and professional judgment.

For additional information and data on pollutant removal capabilities for bioretention areas, see the National Pollutant Removal Performance Database (2nd Edition) available at www.stormwatercenter.net and the International Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

4.3.5.4 Application and Site Feasibility Criteria

Bioretention areas are suitable for many types of development, from single-family residential to high-density commercial projects. Bioretention is also well suited for small lots, including those of 1 acre or less. Because of its ability to be incorporated in landscaped areas, the use of bioretention is extremely flexible. Bioretention areas are an ideal structural stormwater BMP for use as roadway median strips and parking lot islands and are also good candidates for the treatment of runoff from pervious areas, such as a lawn area. Bioretention can also be used to retrofit existing development with stormwater quality treatment capacity.

The following criteria should be evaluated to ensure the suitability of a bioretention area for meeting stormwater management objectives on a site or development.

General Feasibility

- Suitable for Residential Subdivision Usage – YES
- Suitable for Regional Stormwater Control – NO

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – 5 acres maximum; 0.5 to 2 acres are preferred.
- Space Required – Approximately 5% of the tributary impervious area is required; minimum 200 ft^2 area for small sites (10 feet x 20 feet).
- Site Slope – No more than 6% slope in the contributing drainage area.
- Minimum Head – Elevation difference needed at a site from the inflow to the outflow underdrain or pea gravel under-layer: 5 feet.
- Minimum Depth to Water Table – A separation distance of 2 feet is recommended between the bottom of the bioretention facility and the elevation of the seasonally high water table.
- Soils – No restrictions; engineered media required. Karst areas may require a liner.

Other Constraints / Considerations

- Wellhead Protection – Reduce potential groundwater contamination (in required wellhead protection areas) by preventing infiltration of hotspot runoff. May require liner for type “A” and “B” soils; pretreat hotspots; 2 to 4 foot separation distance from water table. Wellhead protection areas may require guidance from other agencies, such as TDEC.

4.3.5.5 Planning and Design Standards

The following standards are to be considered **minimum** standards for the design of a bioretention facility. Consult with the local jurisdiction to determine if there are any variations to these criteria or additional standards that must be followed.

A. LOCATION AND SITING

- Bioretention areas should have a maximum contributing drainage area of 5 acres or less; 0.5 to 2 acres are preferred. Multiple bioretention areas can be used for larger areas.
- Bioretention areas can either be used to capture sheet flow from a drainage area or function as an off-line device. On-line designs should be limited to a maximum drainage area of 0.5 acres.
- When used in an off-line configuration, the WQv is diverted to the bioretention area through the use of a flow splitter or other means. Stormwater flows greater than the WQv are diverted to other controls or downstream (see Chapter 4, Section 4.2 for more discussion of off-line systems and design guidance for diversion structures and flow splitters).
- Bioretention systems are designed for intermittent flow and must be allowed to drain and reaerate between rainfall events. Bioretention systems will not be allowed for sites that have a continuous flow from groundwater, sump pumps, or other sources.
- Aesthetic considerations should be taken into account in the siting and design of bioretention areas. Elevations must be carefully determined to ensure that the desired runoff flow enters the facility with no more than the maximum design depth.
- Each bioretention area shall be placed in an easement that is recorded with the deed. The easement shall be defined at the outer edge of the bioretention cell. Minimum setback requirements for the easement shall be as follows unless otherwise specified by the local jurisdiction:
  - From a property line – 10 feet;

- From a public water system well – TDEC specified distance per designated category;
- From a private well – 100 feet; if well is downgradient from a land use that requires a Special Pollution Abatement Permit, then the minimum setback is 250 feet;
- From a septic system tank/leach field – 50 feet.

B. GENERAL DESIGN

- A bioretention area shall consist of:

  (1) A grass filter strip (or grass channel) between the contributing drainage area and the ponding area,

  (2) A ponding area containing vegetation with a planting soil bed,

  (3) An organic/mulch layer,

  (4) A gravel and perforated pipe underdrain system to collect runoff that has filtered through the soil layers (bioretention areas can optionally be designed to infiltrate into the soil – see description of infiltration trenches for infiltration criteria).

- A bioretention area design may also include some of the following:

  (1) An optional sand filter layer with geotextile fabric to spread flow, filter runoff, and aid in aeration and drainage of the planting soil, located between the underdrain and planting soil.

  (2) A pea gravel diaphragm at the beginning of the grass filter strip to reduce runoff velocities and spread flow into the grass filter.

  (3) Energy dissipation techniques will be required for contributing drainage areas that have a 6% slope or greater.

  (4) Inflow diversion or an overflow structure(s) that are designed based on one of five main methods:

    - Use of a flow diversion structure;
    - Use of curbed pavements as an inlet deflector (see Figure 4-30);
    - Use of a slotted curb along with the design of parking lot grades to divert the WQv into the bioretention facility. Additional runoff will be bypassed to a downstream catch basin inlet. The alternative requires temporary ponding in the parking lot (see Figure 4-29);
    - Figure 4-29 illustrates the use of a short deflector weir (maximum height 6 inches) designed to divert the maximum water quality peak flow into the bioretention area;
    - Use of an in-system overflow consisting of an overflow catch basin inlet and/or a pea gravel curtain drain overflow.

See Figure 4-27 for an overview of the various components of a bioretention area. Figure 4-28 provides a plan view and profile schematic of an on-line bioretention area. An example of an off-line facility is shown in Figure 4-29.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

- The minimum dimensions of a bioretention area shall be 10 feet wide by 20 feet long, or 200 square feet in area for roughly circular designs. All designs, except small residential applications such as bio-retention areas placed in cul-de-sac islands to treat runoff from the surrounding street, shall maintain a length to width ratio of at least 2:1.
- The planting soil filter bed shall be sized using a Darcy's Law equation with a filter bed drain time of 48 hours and a coefficient of permeability (k) of 0.5 ft/day.
- The maximum ponding depth of a bioretention area is 6 inches.

- The planting soil bed shall be at least 4 feet in depth when trees are planted in the bioretention area but can be a minimum of 2 feet deep in facilities that will utilize plants other than trees. Planting soils shall consist of a sandy loam, loamy sand, or loam texture with a clay content ranging from 10 to 25%. The soil must have an infiltration rate of at least 0.5 inches per hour and a pH between 5.5 and 6.5. In addition, the planting soil must have a 1.5 to 3% organic content and a maximum 500 ppm concentration of soluble salts.
- The mulch layer must consist of 2 to 4 inches of commercially available fine shredded hardwood mulch or shredded hardwood chips.
- The sand bed must be 12 to 18 inches thick. Sand shall be clean and have less than 15% silt or clay content.
- Pea gravel for the diaphragm and curtain, when used, should be ASTM D 448 size No. 6 (1/8" to ¼").
- The underdrain collection system shall include a 4 to 6 inch pipe wrapped in a 6 to 8 inch gravel layer. The pipe shall have 3/8-inch perforations, spaced at 6-inch centers, with a minimum of 4 holes per row around the circumference of the pipe. The pipe spacing shall be at a maximum of 10 feet on center and a minimum grade of 0.5% must be maintained. A permeable filter fabric shall be required between the gravel layer and the planting soil bed. High density polyethylene (HDPE) pipe is the preferred pipe material, however other suitable pipe materials may be approved.

D. PRETREATMENT / INLETS

- Adequate pretreatment and inlet protection for bioretention systems shall be provided, such as: a grass filter strip below a flow spreader, or a grass channel, or a pea gravel diaphragm.
- For on-line configurations, a grass filter strip with a pea gravel diaphragm or other flow spreader shall be utilized (see Figure 4-28) as the pretreatment measure. The required length of the filter strip depends on the drainage area, imperviousness, and the filter strip slope. Design guidance on filter strips for pretreatment can be found in Chapter 4, Section 4.3.9 of this manual.
- For off-line applications, a grass channel with a pea gravel diaphragm or other flow spreader shall be used for pretreatment. The length of the grass channel depends on the drainage area, land use, and channel slope. The minimum grassed channel length shall be 20 feet. Design guidance on grass channels for pretreatment can be found in Chapter 4, Section 4.3.10 of this manual.

E. OUTLET STRUCTURES

- For bioretention areas placed in soils having a hydrologic soil group designation of C or D, an outlet pipe shall be provided from the underdrain system to the facility discharge. Outlet pipes are optional for group B soils. Discharges shall not exit the outlet pipe in an erosive manner. Due to the slow rate of discharge, outlet erosion protection is generally unnecessary.

F. EMERGENCY SPILLWAY

- An emergency spillway shall be included per regulations of the local jurisdiction.

G. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right-of-way or easement shall be provided from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.
- The maintenance access shall be designed such that all areas of the bioretention area can be easily accessed, and shall be designed to allow vehicles to turn around.

H. SAFETY FEATURES

- Bioretention areas generally do not require any special safety features. Fencing of bioretention facilities is not generally desirable.

I. LANDSCAPING

- Landscaping is critical to the performance and function of bioretention areas.
- A dense and vigorous vegetative cover that is appropriate for use in a bioretention area shall be established over the contributing pervious drainage areas before runoff can be accepted into the facility. When the contributing drainage area is completely or partially disturbed or unstabilized, sediment laden runoff reaching the bioretention can clog the soils and cause the bioretention are to fail.
- In general, vegetation utilized in the bioretention area should be native to East Tennessee, resistant to drought and inundation, tolerant of pollutants, have low fertilization requirements, and be easily maintained. Grasses, shrubs, and trees are all permissible vegetation types for bioretention areas, as long as the species used meet the general guidance provided herein.
- Bioretention areas that will contain trees shall be vegetated as follows:
  - The bioretention area shall be vegetated to resemble a terrestrial forest ecosystem, with a mature tree canopy, subcanopy of understory trees, shrub layer, and herbaceous ground cover. Three species each of both trees and shrubs are recommended to be planted.
  - The tree-to-shrub ratio should be 2:1 to 3:1. On average, the trees should be spaced 8 feet apart. Plants should be placed at regular intervals to replicate a natural forest. Woody vegetation should not be specified at inflow locations.
  - After the trees and shrubs are established, the ground cover and mulch should be established.

Additional information and guidance on bioretention area design and vegetation can be found on the EPA website at http://cfpub.epa.gov/npdes/stormwater and on the North Carolina State University Biological and Agricultural Engineering website at http://bae.ncsu.edu/stormwater/ .

J. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

Physiographic Factors - Local terrain design constraints

- Low Relief – Use of bioretention areas may be limited by low head.
- High Relief – Ponding area surface must be relatively level.
- Karst – Use poly-liner or impermeable membrane to seal bottom.

Soils

- No restrictions, however, planting soil must meet the required design infiltration rate.

Special Downstream Watershed Considerations

- Wellhead Protection – Reduce potential groundwater contamination (in required wellhead protection areas) by preventing infiltration of hotspot runoff. May require liner for type “A” and “B” soils; pretreat hotspots; 2 to 4 foot separation distance from water table. Wellhead protection areas may require guidance from other agencies, such as TDEC.

4.3.5.6 Design Procedures

Step 1. Compute runoff control volumes

> Calculate the locally regulated peak discharge, in accordance with the guidance presented in Chapter 3.

Step 2. Determine if the development site and conditions are appropriate for the use of a bioretention area

> Consider the subsections 4.3.5.4 and 4.3.5.5-A (Location and Siting).

Step 3. Confirm design criteria and applicability

Consider any special site-specific design conditions/criteria from subsection 4.3.5.5-J (Additional Site-Specific Design Criteria and Issues).

Check with the local jurisdiction and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 4. Compute WQv peak discharge (Q_{wq})

The peak rate of discharge for water quality design storm is needed for sizing of off-line diversion structures (see Chapter 3 for more detail).

(a) Using WQv (or total volume to be captured), compute CN

(b) Compute time of concentration using TR-55 method

(c) Determine appropriate unit peak discharge from time of concentration

(d) Compute Q_{mg} from unit peak discharge, drainage area, and WQv.

Step 5. Size flow diversion structure, if needed

A flow regulator (or flow splitter diversion structure) should be supplied to divert the WQv to the bioretention area.

Size low flow orifice, weir, or other device to pass Q_{wq}.

Step 6. Determine size of bioretention ponding/filter area

The required planting soil filter bed area is computed using the following equation (based on Darcy's Law):

$$A_f = \frac{(WQ_v)(d_f)}{[(k)(h_f + d_f)(t_f)]}$$

where:

A_f = surface area of ponding area (ft^2)
WQv = water quality volume (or total volume to be captured)
d_f = filter bed depth
(4 feet minimum)
k = coefficient of permeability of filter media (ft/day)
(use 0.5 ft/day for silt-loam)
h_f = average height of water above filter bed (ft)
(typically 3 inches, which is half of the 6-inch ponding depth)
t_f = design filter bed drain time (days)
(2.0 days or 48 hours is recommended maximum)

Step 7. Set design elevations and dimensions of facility

See subsection 4.3.5.5-C (Physical Specifications/Geometry).

Step 8. Design conveyances to facility (off-line systems)

See the example figures to determine the type of conveyances needed for the site.

Step 9. Design pretreatment

Pretreat with a grass filter strip (on-line configuration) or grass channel (off-line), and stone diaphragm.

Step 10. Size underdrain system

See subsection 4.3.5.5-C (Physical Specifications/Geometry)

Step 11. Design emergency overflow

An emergency spillway shall be included per regulations of the local jurisdiction.

Step 12. Design vegetation

A landscaping plan for the bioretention area should be prepared to indicate how it will be established with vegetation.

See subsection 4.3.5.5-I (Landscaping) for more details.

This space intentionally left blank

4.3.5.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.5.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of bioretention areas as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local jurisdiction has the authority to impose additional maintenance requirements where deemed necessary.

This section provides guidance on maintenance activities that are typically required for bioretention areas, along with a suggested frequency for each activity. Individual bioretention areas may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e.., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the basin in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• After several storm events or an extreme storm event, inspect for signs of erosion, signs of mulch movement out of the treatment area, signs of damage to plants or dead or diseased vegetation.	As needed
• Inspect: inflow points for clogging (off-line systems), strip/grass channel for erosion or gullying, • Inspect trees, shrubs and other vegetation to evaluate their health and replace any dead or diseased vegetation. • Inspect surrounding drainage area for erosion or signs of sediment delivery to the bioretention area.	Semi-annually
• Check for signs of vegetation overgrowth. • Inspect treatment area during a rain event and visually verify that stormwater recedes within 24-48 hours from the treatment area.	Annually
Maintenance Activities	**Suggested Schedule**
• Replace mulch and repair areas of erosion, when identified. • Replace dead or diseased plants.	As needed
• Remove clogs from the stormwater system inflow and overflow components. • Remove sediments from pretreatment areas and restabilize with stone or vegetation as appropriate.	Semi-annually
• Harvest overgrown vegetation and remove from the bioretention area.	As Needed
• 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. • Check that planting soils still have infiltration rate.	Annually
• Replace mulch over the entire area. • Replace pea gravel diaphragm if warranted. • Note that the surface of the ponding area may become clogged with fine sediment over time. Core aeration or cultivating of un-vegetated areas may be required to ensure adequate filtration.	2 to 3 years

The local jurisdiction encourages the use of the inspection checklist that is presented on the next page to guide the property owner in the inspection and maintenance of bioretention areas. The local jurisdiction can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the bioretention area. Questions regarding stormwater facility inspection and maintenance should be referred to the local jurisdiction.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
BIORETENTION AREA INSPECTION CHECKLIST

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone:____

Date: ___________ Time: ______________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Inflow and Overflow Points		
Clear of debris and functional?		
Sediment accumulation?		
Vegetation in good condition?		
Signs of erosion?		
Other (describe)?		
Sediment Pretreament		
Evidence of sediment accumulation?		
Treatment Area and Vegetation		
Signs of erosion or movement of mulch?		
Vegetation healthy or damaged?		
Signs of sediment?		
Signs of thinning mulch layer?		
Vegetation overgrown and in need of harvesting?		
Standing water for more than 24-48 hours after rain events?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:_______________________________ Inspector Name (printed)___________________________

4.3.5.8 Example Schematics

Figure 4-27. Schematic of a Typical Bioretention Area

(Source: Claytor and Schueler, 1996)

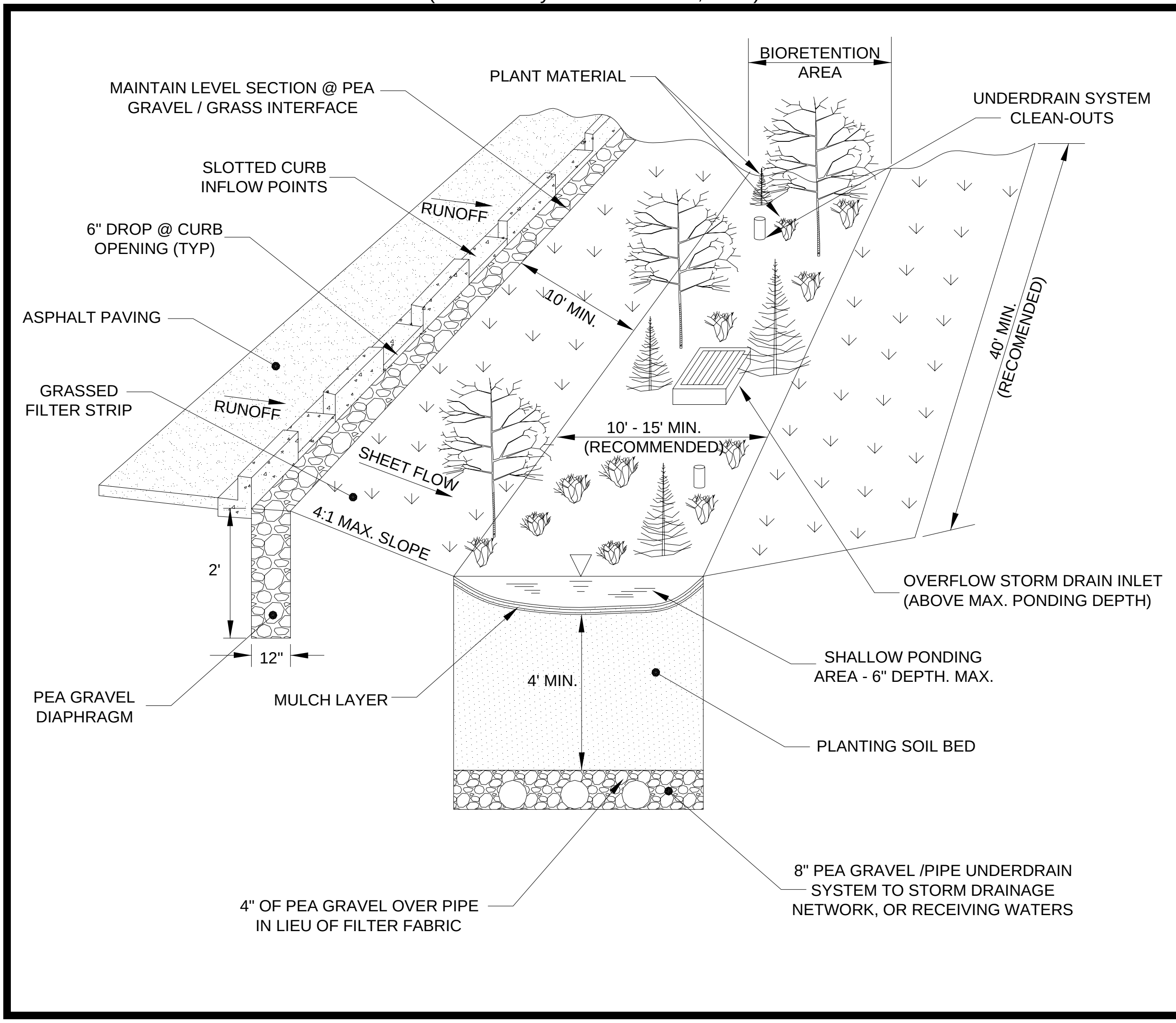


Figure 4-28. Schematic of a Typical On-line Bioretention Area

(Source: Claytor and Schueler, 1996)

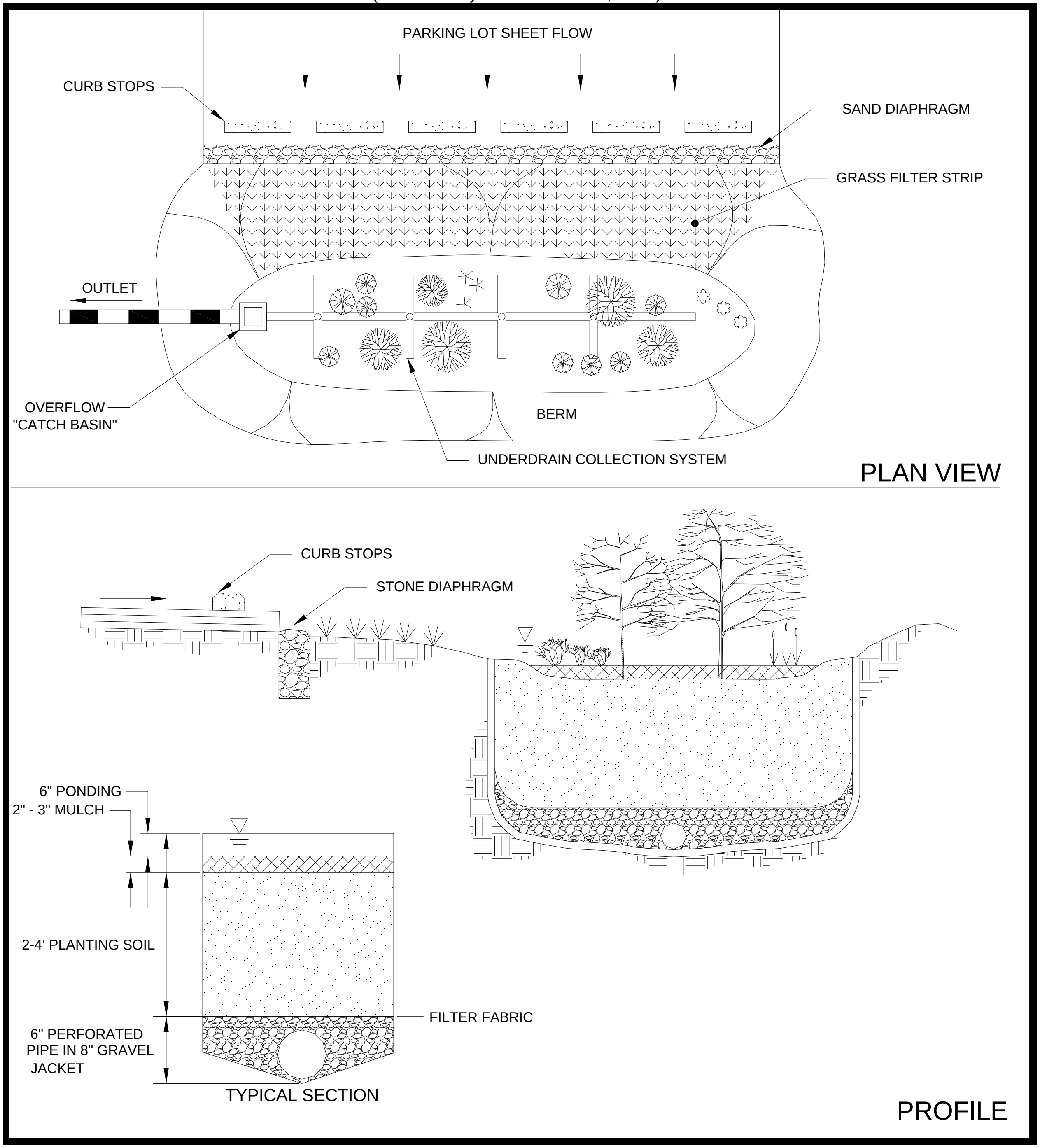


Figure 4-29. Schematic of a Typical Off-line Bioretention Area

(Source: Claytor and Schueler, 1996)

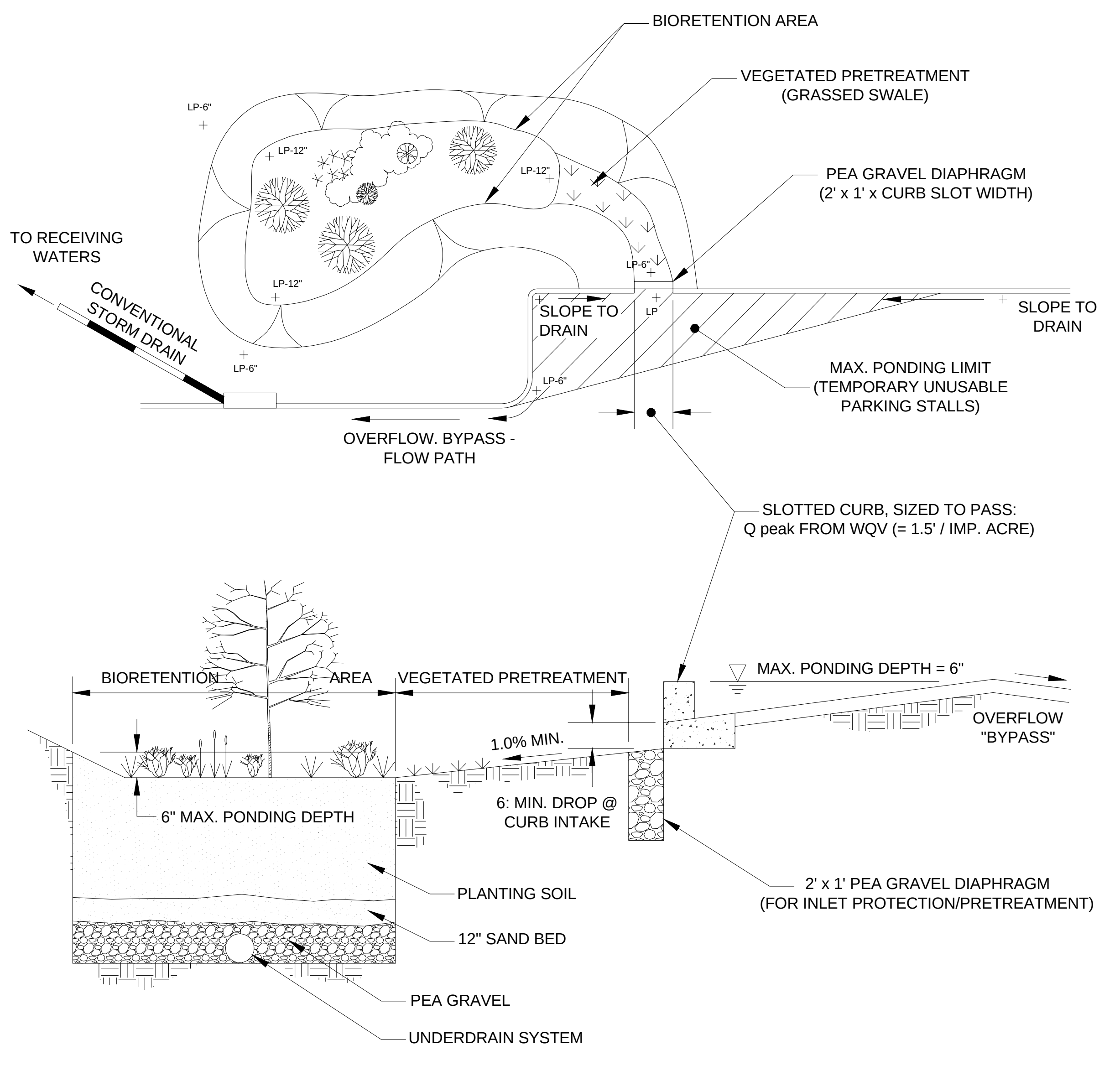
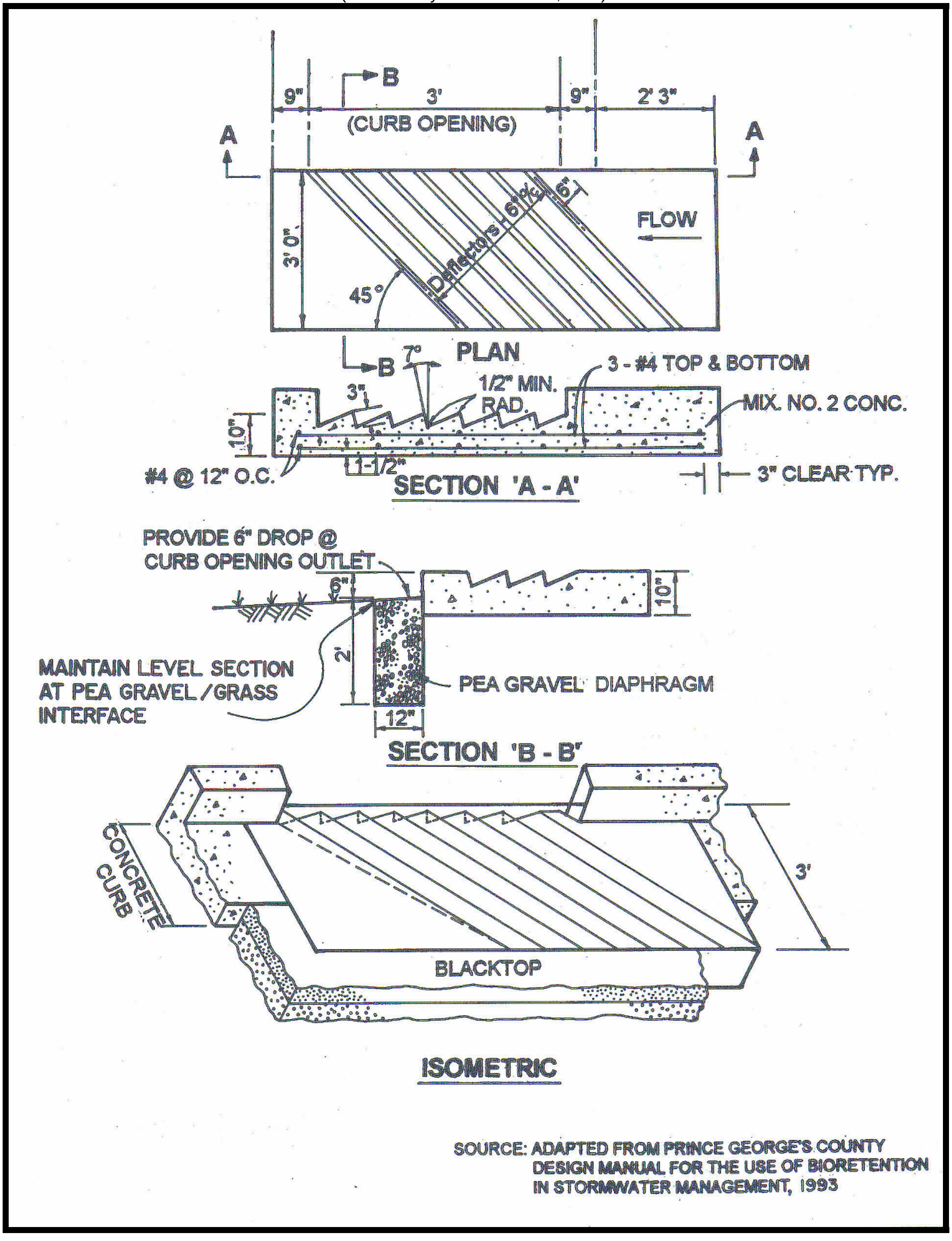


Figure 4-30. Schematic of a Typical Inlet Deflector
(Source: Claytor and Schueler, 1996)



4.3.5.9. Design Form

The local jurisdiction recommends the use of the following design procedure forms when designing a bioretention area. Proper use and completion of the form may allow a faster review of the Stormwater Management Plan by the local jurisdiction.

Design Procedure Form: Bioretention Areas

PRELIMINARY HYDROLOGIC CALCULATIONS	
1a. Compute WQv volume requirements Compute Runoff Coefficient, Rv Compute WQv	 Rv = ________ WQv = ________ acre-ft
1b. Compute CPv	CPv = ________ acre-ft
BIORETENTION AREA DESIGN	
2. Is the use of a bioretention area appropriate?	***See subsections 4.3.5.4 and 4.3.5.5 - A***
3. Confirm design criteria and applicability.	***See subsection 4.3.5.5 - J***
4. Determine size of bioretention filter area	A_f= ________ ft^2
5. Set design elevations and dimensions	Length = ________ ft Width = ________ ft ________ elevation top of facility ________ other elev: ________ other elev: ________ other elev:
6. Conveyance to bioretention facility	________ Online or ________ Offline ?
7. Pretreatment	Type: ________
8. Size underdrain area Based on guidance: Approx. 10% A_f	Length= ________ ft
9. Overdrain design	Type: ________ Size: ________
10. Emergency storm weir design Overflow weir - Weir equation	Length= ________ ft
11. Choose plants for planting area	Select native plants based on resistance to drought and inundation, cost, aeshetics, maintenance, etc.
12. Verify peak flow control, water quality drawdown time and channel protection detention time	

4.3.5.10 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual, Volume 2: Technical Handbook.* 2001.

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center, Accessed July 2005. www.stormwatercenter.net

City of Nashville, Tennessee. *Metropolitan Nashville and Davidson County Stormwater Management Manual, Volume 4 Best Management Practices.* 2006.

City of Portland, OR. *Stormwater Management Manual.* 2004.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

Prince George's County. *Design Manual for Use of Bioretention in Stormwater Management.* Department of Environmental Resources, Prince George's County, Landover, MD, 1993.

4.3.5.11 Suggested Reading

Bell, W. *BMP Technologies for Ultra-Urban Settings. In Proceedings of Effective Land Management for Reduced Environmental Impact.* Tidewater's Land Management Conference on Water Quality, August 22, 1996.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

US EPA. *Storm Water Technology Fact Sheet: Bioretention.* EPA 832-F-99-012, Office of Water, 1999.

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

Washington State Department of Transportation (WSDOT). *Highway Runoff Manual.* Washington State Department of Transportation, 1995.

4.3.6 Surface Sand Filters

**General Application
Water Quality BMP**

Description: Surface sand filters are multi-chamber structures located above ground that are designed to treat stormwater runoff through filtration, using a sediment forebay, a sand bed as its primary filter media and, typically, an underdrain collection system.

KEY DESIGN CONSIDERATIONS

DESIGN GUIDELINES:

- Typically requires 2 to 6 feet of head.
- Maximum contributing drainage area of 10 acres for surface sand filter; 2 acres for perimeter sand filter.
- Sand filter media with underdrain system.
- Typically needs to be combined with other controls to provide water quality control.

ADVANTAGES / BENEFITS:

- Applicable to small drainage areas.
- Good for highly impervious areas.
- Good retrofit capability.

DISADVANTAGES / LIMITATIONS:

- High maintenance burden.
- Not recommended for areas with high sediment content in stormwater or clay/silt runoff areas.
- Relatively costly.
- Possible odor problems.
- Cannot be installed until site construction is complete.

MAINTENANCE REQUIREMENTS:

- Inspect for clogging – rake first inch of sand.
- Remove sediment from forebay/chamber.
- Replace sand filter media as needed.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	✷
Detention/Retention:	**No**

✷ in certain situations

Accepts hotspot runoff: *Yes (requires impermeable liner)*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**High**
Maintenance Burden:	**High**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**No**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**80%**

4.3.6.1 General Description

Surface sand filters (also referred to as *sand filters* or *filtration basins*) are ground-level, open air structures that capture and temporarily store stormwater runoff and pass it through a filter bed of sand. An example of a surface sand filter is presented in Figure 4-31. Underground sand filters, discussed in Section 4.4.2, treat stormwater in the same manner, but are located below the ground surface. Because of the increased maintenance requirements, underground sand filters are considered Limited Application BMPs.

Figure 4-31. Example of a Surface Sand Filter

Most sand filter systems, surface and underground, consist of two-chamber structures. The first chamber is a sediment forebay or sedimentation chamber, which removes floatables and heavy sediments. The second is the filtration chamber, which removes finer sediments and other pollutants by filtering the runoff through a sand bed. The filtered runoff is typically collected and returned to the conveyance system, though it can also partially or fully permeate into the surrounding soil in areas with porous soils.

This system can treat drainage areas up to 10 acres in size and is typically located off-line. Surface sand filters can be designed as an excavation with earthen embankments or as a concrete or block structure. Because they have few site constraints beside head requirements, sand filters can be used on development sites where the use of other structural BMPs may be precluded. However, sand filter systems can be relatively expensive to construct and install, and require a relatively high level of maintenance and inspection. Because of this, surface sand filters are not recommended for use in residential areas.

4.3.6.2 Stormwater Management Suitability

Surface sand filter systems are designed primarily as <u>off-line</u> systems for treatment of the water quality volume and will typically need to be used in conjunction with another structural BMP that can provide downstream channel protection and protection of the locally regulated peak discharge. However, under certain circumstances, filters can provide limited runoff quantity control, particularly for smaller storm events.

Water Quality (WQv)
In sand filter systems, stormwater pollutants are removed through a combination of gravitational settling, filtration and adsorption. The filtration process effectively removes suspended solids and particulates, biochemical oxygen demand (BOD), fecal coliform bacteria, and other pollutants. Surface sand filters with a grass cover have additional opportunities for bacterial decomposition as well as vegetation uptake of pollutants, particularly nutrients.

Channel Protection (CPv)
For smaller sites, a sand filter may be designed to capture the entire channel protection volume (CPv) in either an off- or on-line configuration. Given that a sand filter system is typically designed to completely drain over 40 hours, the channel protection design requirement for extended detention of the 1-year, 24-hour storm runoff volume can be met. For larger sites or where only the WQv is diverted to the sand filter facility, another structural control must be used to provide extended detention of the CPv.

4.3.6.3 Pollutant Removal Capabilities

Surface sand filters are presumed to be able to remove 80% of the total suspended solids (TSS) load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. Undersized or poorly designed sand filters can reduce TSS removal performance.

The total suspended solids design pollutant removal rate of 80% is a conservative average pollutant reduction percentage for design purposes derived from sampling data, modeling and professional judgment.

For additional information and data on pollutant removal capabilities for sand filters, see the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the International Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

4.3.6.4 Application and Site Feasibility Criteria

Surface sand filter systems are well-suited for highly impervious areas where land available for structural BMPs is limited. Sand filters should primarily be considered for new construction or retrofit opportunities for commercial, industrial, and institutional areas where the sediment load is relatively low, such as: parking lots, driveways, loading docks, gas stations, garages, airport runways/taxiways, and storage yards. Sand filters may also be feasible and appropriate in some multi-family residential developments where maintenance is performed by a landscaping (or other suitably capable) company.

To avoid rapid clogging and failure of the filter media, the use of sand filters should be avoided in areas with less than 50% impervious cover, or high sediment yield sites with clay/silt soils.

The following basic criteria should be evaluated to ensure the suitability of a sand filter facility for meeting stormwater management objectives on a site or development.

General Feasibility

- Not suitable for use in a residential subdivision
- Suitable for use in high density/ultra-urban areas
- Not suitable for use as a regional stormwater control. On-site applications are typically most feasible.

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – 10 acres maximum for surface sand filter; 2 acres maximum for perimeter sand filter
- Space Required – Function of available head at site
- Minimum Head – The surface slope across the filter location should be no greater than 6%. The elevation difference needed at a site from the inflow to the outflow: 5 feet for surface sand filters; 2 to 3 feet for perimeter sand filters.

- Minimum Depth to Water Table – If used on a site with an underlying water supply aquifer, a separation distance of 2 feet is required between the bottom of the sand filter and the elevation of the seasonally high water table to prevent groundwater contamination.
- Soils – Not recommended for clay/silt drainage areas that are not stabilized. Karst areas may require a liner.

Other Constraints / Considerations

- Aquifer Protection – Do not allow infiltration of filtered hotspot runoff into groundwater

4.3.6.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of sand filters. Sand filters that are not designed to these standards will not be approved. The local jurisdiction shall have the authority to require additional design conditions if deemed necessary.

A. CONSTRUCTION SEQUENCING

- Ideally, the construction of a sand filter shall take place **after** the construction site has been stabilized.
- In the event that the sand filter is not constructed after site stabilization, care shall be taken during construction to minimize the risk of premature failure of the sand filter due to deposition of sediments from disturbed, unstabilized areas.
- Diversion berms and erosion prevention and sediment controls shall be maintained around the sand filter during all phases of construction. No runoff or sediment shall enter the sand filter area prior to completion of construction and the complete stabilization of construction areas.
- Sand filters may be used as a temporary sediment trap for construction activities if all accumulated sediment is removed from the pit prior to sand placement.
- During and after excavation of the sand filter, all excavated materials shall be placed downstream, away from the sand filters, to prevent redeposit of the material during runoff events.

B. LOCATION AND SITING

- Surface sand filters shall have a contributing drainage area of 10 acres or less.
- Surface sand filter systems are generally applied to land uses with a high percentage of impervious surfaces. Sand filters shall not be utilized for sites that have less than 50% impervious cover. Pretreatment must be provided as described in part D below, due to the potential for high clay/silt sediment loads that could result in clogging and failure of the filter bed. Any disturbed or denuded areas located within the area draining to and treated by the sand filter shall be stabilized prior to construction and use of the sand filter. The sand filter shall only be constructed after the construction site is stabilized.
- It is preferred that surface sand filters are to be used in an off-line configuration where the water quality volume (WQv) is diverted to the filter facility through the use of a flow diversion structure and flow splitter. Stormwater flows greater than the WQv shall be diverted to other controls or downstream using a diversion structure or flow splitter. In certain situations, as determined by the local jurisdiction, a surface sand filter may be used in an on-line configuration.
- Sand filter systems shall be designed for intermittent flow and must be allowed to drain and re-aerate between rainfall events. They shall not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.
- Each sand filter shall be placed in an easement that is recorded with the deed. The easement shall be defined at the outer edge of the sand filter. Minimum setback requirements for the easement shall be as follows unless otherwise specified by the local jurisdiction:
    - From a property line – 10 feet;
    - From a public water system well – TDEC specified distance per designated category;

- From a private well – 100 feet; if well is downgradient from a land use that requires a Special Pollution Abatement Permit, then the minimum setback is 250 feet;
- From a septic system tank/leach field – 50 feet.

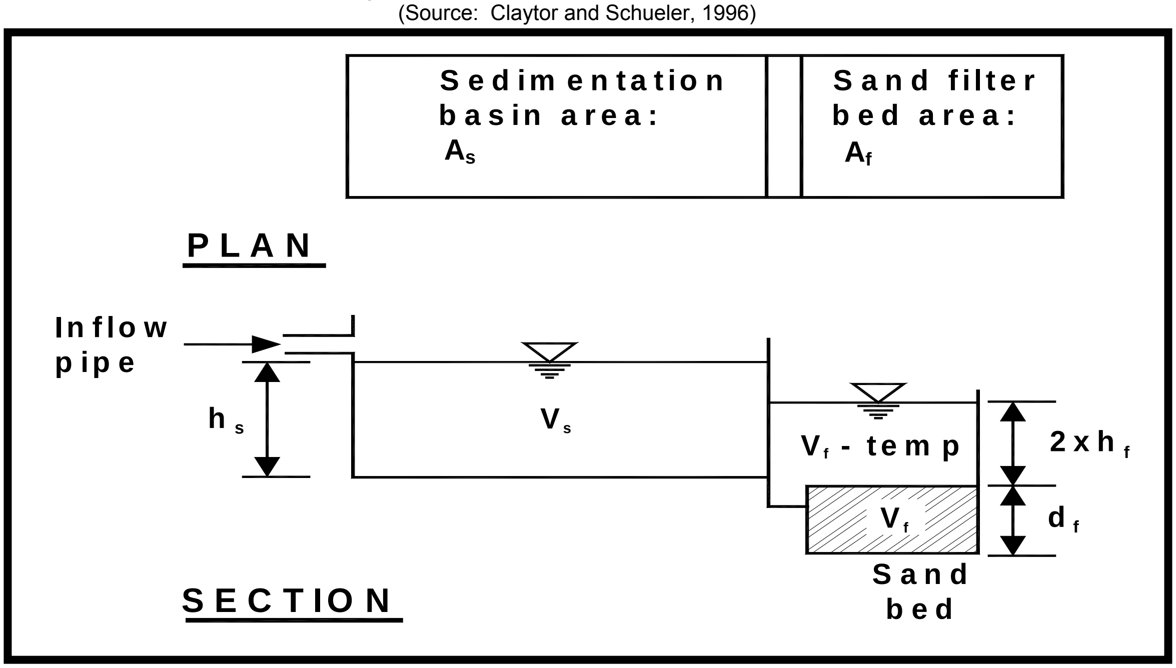
C. GENERAL DESIGN

- A surface sand filter facility shall consist of a two-chamber open-air structure, which is located at ground-level. The first chamber is the sediment forebay (commonly referred to as the sedimentation chamber) while the second chamber houses the sand filter bed. Flow enters the sedimentation chamber where settling of larger sediment particles occurs. Runoff is then discharged from the sedimentation chamber through a perforated standpipe into the filtration chamber. After passing though the filter bed, runoff is collected by a perforated pipe and gravel underdrain system.

D. PHYSICAL SPECIFICATIONS / GEOMETRY

- The entire treatment system (including the sedimentation chamber) shall be designed to temporarily hold at least 75% of the WQv prior to filtration. Figure 4-32 illustrates the distribution of the treatment volume (0.75 WQv) among the various components of the surface sand filter, including:
  - V_s – volume within the sedimentation basin
  - V_f – volume within the voids in the filter bed
  - $V_{f\text{-}temp}$ – temporary volume stored above the filter bed
  - A_s – the surface area of the sedimentation basin
  - A_f – surface area of the filter media
  - h_s – height of water in the sedimentation basin
  - h_f – average height of water above the filter media
  - d_f – depth of filter media

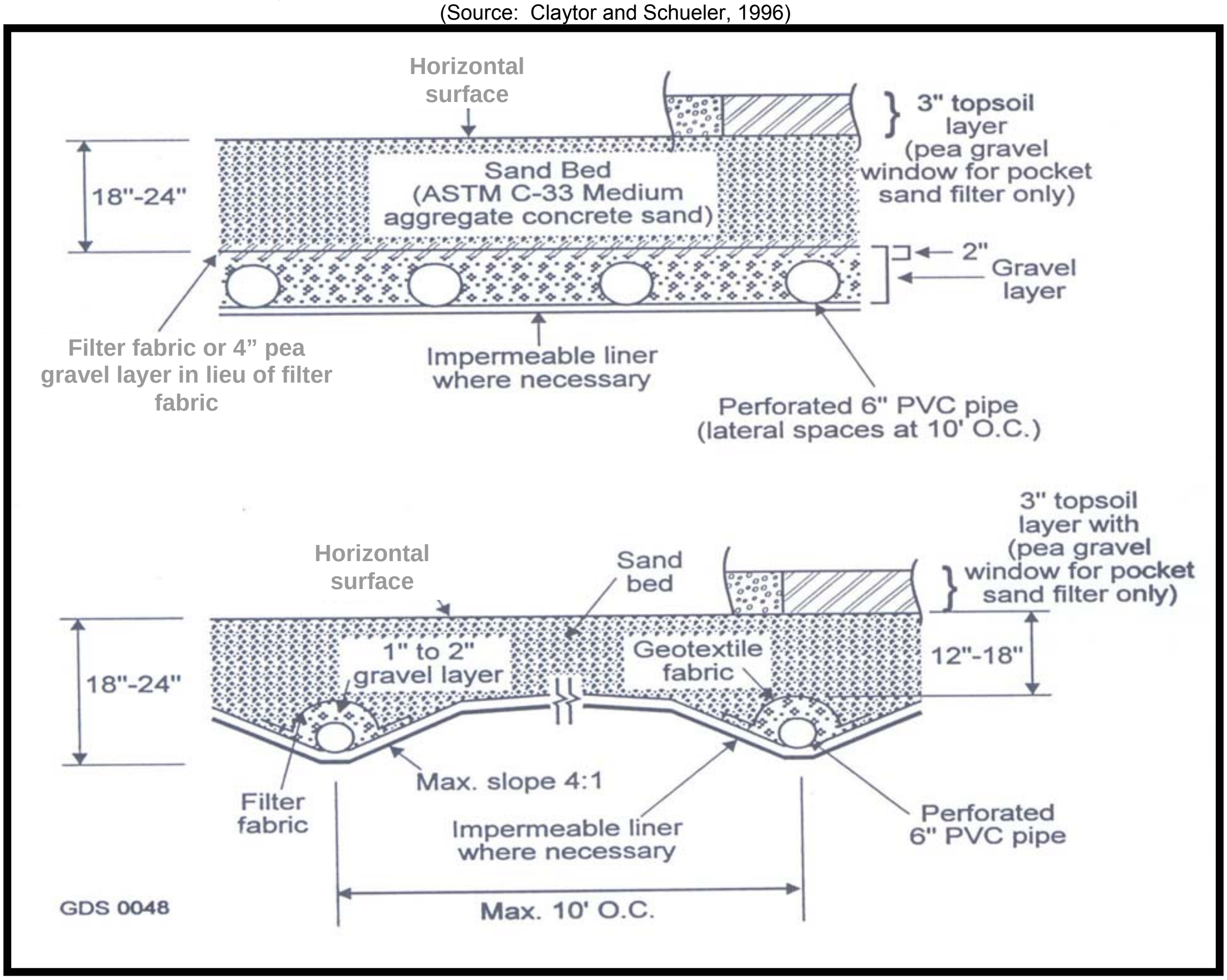
Figure 4-32. Surface Sand Filter Volumes
(Source: Claytor and Schueler, 1996)



- The sedimentation chamber shall be sized to hold at least 25% of the computed WQv and have a length-to-width ratio of at least 2:1. Inlet and outlet structures should be located at opposite ends of the chamber.

- The filter area shall be sized based on the principles of Darcy's Law. A coefficient of permeability (k) of 3.5 ft/day for sand shall be used. The filter bed shall be designed to completely drain in 40 hours or less.
- The filter media shall consist of an 18-inch layer of clean washed medium aggregate concrete sand (ASTM C-33) on top of the underdrain system. Three inches of topsoil shall be placed over the sand bed. Permeable filter fabric shall be placed both above and below the sand bed to prevent clogging of the sand filter and the underdrain system. Figure 4-33 illustrates a typical media cross section.
- The filter bed shall be equipped with a 6-inch perforated pipe underdrain (PVC AASHTO M 252, HDPE, or other suitable pipe material) in a gravel layer. The underdrain shall have a minimum grade of 1/8-inch per foot (1% slope). Holes shall be 3/8-inch diameter and spaced approximately 6 inches on center. Gravel shall be clean-washed aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches with a void space of about 40%. Aggregate contaminated with soil shall not be used.
- The structure of the surface sand filter may be constructed of impermeable media such as concrete, or through the use of excavations and earthen embankments. When constructed with earthen walls/embankments, filter fabric shall be used to line the bottom and side slopes of the structures before installation of the underdrain system and filter media.

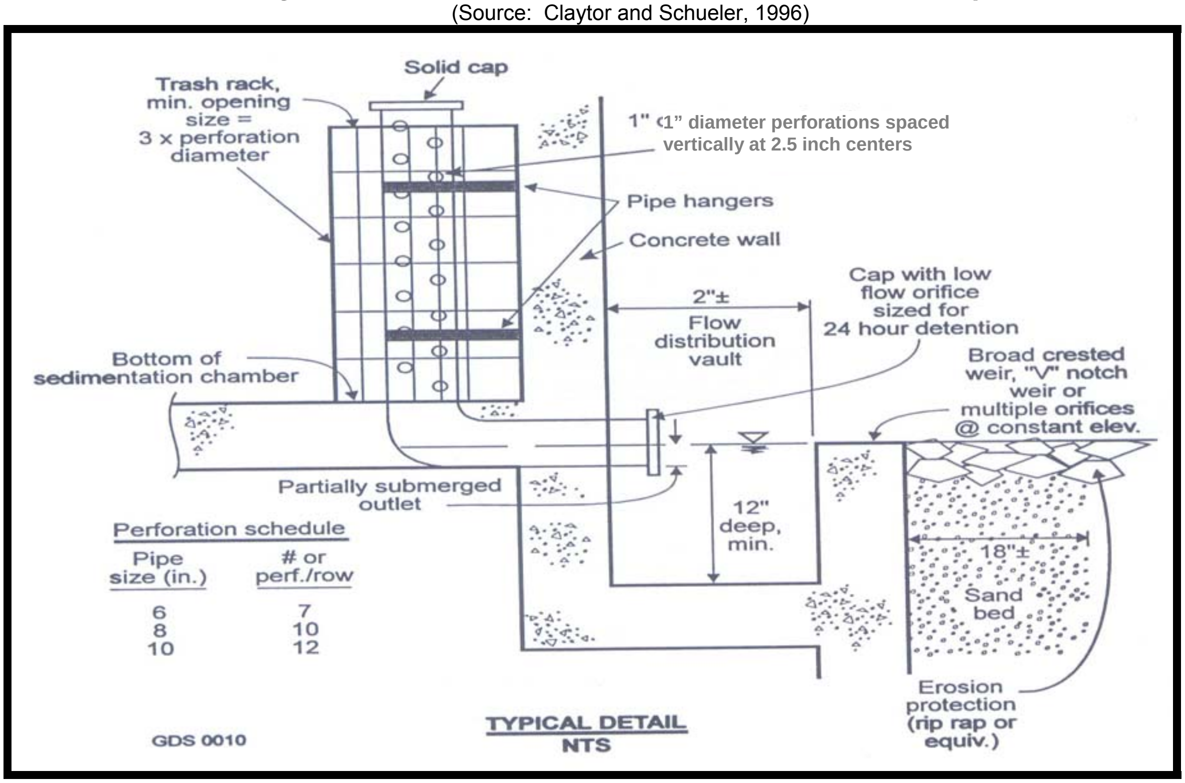
Figure 4-33. Typical Sand Filter Media Cross Sections
(Source: Claytor and Schueler, 1996)



E. PRETREATMENT / INLETS

- Pretreatment of runoff in a sand filter system shall be by a sedimentation chamber, designed in accordance with the criteria stated above.
- Energy dissipators shall be used at the inlets to surface sand filters. Figure 4-34 shows a typical inlet pipe from the sedimentation basin to the filter media basin for the surface sand filter.
- The sand filter shall be designed so that runoff exits the chamber at a non-erosive velocity.

Figure 4-34. Surface Sand Filter Perforated Stand-Pipe
(Source: Claytor and Schueler, 1996)



F. OUTLET STRUCTURES

- An outlet pipe shall be provided from the underdrain system to the facility discharge. Due to the slow rate of filtration, outlet protection is generally unnecessary (except for emergency overflows and spillways). However, the design shall ensure that the discharges from the underdrain system occur in a non-erosive manner.

G. EMERGENCY SPILLWAY

- An emergency or bypass spillway must be included in the surface sand filter design to safely pass flows that exceed the WQv (and CPv if the filter is utilized for channel protection purposes). The spillway prevents filter water levels from overtopping the embankment and causing structural damage. The emergency spillway shall be located so that embankments, downstream buildings and structures will not be impacted by spillway discharges.

H. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right of way or drainage easement shall be provided for a sand filter from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles. Facility designs must enable maintenance personnel to easily remove and replace the filter media.

I. SAFETY FEATURES

- Where necessary, surface sand filter facilities can be fenced to prevent access.

J. LANDSCAPING

- Surface sand filters can be designed with a grass cover to aid in pollutant removal and prevent clogging. The grass should be capable of withstanding frequent periods of inundation and drought.

K. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

Physiographic Factors - Local terrain design constraints

- Low Relief – Use of surface sand filter may be limited by low head
- High Relief – Filter bed surface must be level
- Karst – Use liner or impermeable membrane to seal bottom earthen surface of the sand filter or use watertight structure

Special Downstream Watershed Considerations

- Wellhead Protection – Reduce potential groundwater contamination (in required wellhead protection areas) by preventing infiltration of hotspot runoff. May require liner for type "A" and "B" soils; Pretreat hotspots; provide 2 to 4 foot separation distance from water table

4.3.6.6 Design Procedures

Step 1. Compute runoff control volumes

Calculate WQv, CPv, and the locally regulated peak discharges, in accordance with the guidance presented in Chapter 3.

Step 2. Determine if the development site and conditions are appropriate for the use of a surface sand filter.

Consider the Application and Site Feasibility Criteria, and the Additional Site Specific Design Criteria and Issues noted above. Check with the local jurisdiction and other agencies as appropriate to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 3. Compute WQv peak discharge (Q_{wq})

The peak rate of discharge for water quality design storm is needed for sizing of off-line diversion structures (see Chapter 3 for more information on this calculation).

(1) Using WQv, compute CN

(2) Compute time of concentration using TR-55 method

(3) Determine appropriate unit peak discharge from time of concentration

(4) Compute Q_{wq} in inches from unit peak discharge, drainage area, and WQv.

Step 4. Size flow diversion structure, if needed

A flow regulator (or flow splitter diversion structure) should be supplied to divert the WQv to the sand filter facility. Size low flow orifice, weir, or other device to pass Q_{wq}.

Step 5. Size filtration basin chamber

The filter area is sized using the following equation (based on Darcy's Law):

$$A_f = (WQv)\,(d_f) \,/\, [(k)\,(h_f + d_f)\,(t_f)]$$

where:

A_f = surface area of filter bed (ft^2)

d_f = filter bed depth (1.5 ft) (at least 18 inches, no more than 24 inches)
k = coefficient of permeability of filter media (ft/day) (use 3.5 ft/day for sand)
h_f = average height of water above filter bed (ft)
(1/2 h_{max}, which varies based on site but h_{max} is typically ≤ 6 feet)
t_f = design filter bed drain time (days) (1.67 days or 40 hours is maximum time)

Set preliminary dimensions of filtration basin chamber.

Step 6. Size sedimentation chamber

The sedimentation chamber shall be sized to at least 25% of the computed WQv and have a length-to-width ratio of 2:1. The Camp-Hazen equation is used to compute the required surface area:

$$A_s = -(Q_o/w) * \text{Ln}(1-E)$$

where:

A_s = sedimentation basin surface area (ft^2)
Q_o = rate of outflow = the WQv (ft^3) / 86400 seconds
w = particle settling velocity (ft/sec)
E = trap efficiency

Assuming:

- 90% sediment trap efficiency (0.9)
- particle settling velocity (ft/sec) = 0.0033 ft/sec for imperviousness ≥ 75%
- particle settling velocity (ft/sec) = 0.0004 ft/sec for imperviousness < 75%
- average of 24 hour holding period

Then:

A_s = (0.0081) (WQv) ft^2 for I ≥ 75%
A_s = (0.066) (WQv) ft^2 for I < 75%

Set preliminary dimensions of sedimentation chamber.

Step 7. Compute V_{min}

$$V_{min} = 0.75 * WQv$$

Step 8. Compute storage volumes within entire facility and sedimentation chamber orifice size

$$V_{min} = 0.75\ WQv = V_s + V_f + V_{f\text{-}temp}$$

(1) Compute V_f = water volume within filter bed/gravel/pipe = $A_f * d_f * n$
Where: n = porosity = 0.4 for most applications

(2) Compute $V_{f\text{-}temp}$ = temporary storage volume above the filter bed = $2 * h_f * A_f$

(3) Compute V_s = volume within sediment chamber = $V_{min} - V_f - V_{f\text{-}temp}$

(4) Compute h_s = height in sedimentation chamber = V_s/A_s

(5) Ensure h_s and h_f fit available head and other dimensions still fit – change as necessary in design iterations until all site dimensions fit.

(6) Size orifice from sediment chamber to filter chamber to release V_s within 24-hours at average release rate with 0.5 h_s as average head.

(7) Design outlet structure with perforations allowing for a safety factor of 10 times the orifice capacity.

(8) Size distribution chamber to spread flow over filtration media – level spreader weir or orifices.

Step 9. Design inlets, pretreatment facilities, underdrain system, and outlet structures

See design criteria above for more details.

Step 10. Compute overflow weir sizes

(1) Size overflow weir at elevation hs in sedimentation chamber (above perforated stand pipe) to handle surcharge of flow through filter system from 25-year storm.

(2) Plan inlet protection for overflow from sedimentation chamber and size overflow weir at elevation hf in filtration chamber (above perforated stand pipe) to handle surcharge of flow through filter system from 25-year storm.

This space intentionally left blank

4.3.6.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.6.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of a sand filter as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local jurisdiction has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for sand filters, along with a suggested frequency for each activity. Individual sand filters may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e.., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the sand filter in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• A record should be kept of the dewatering time (i.e., the time required to drain the filter bed completely after a storm event) for a sand filter to determine if maintenance is necessary. The filter bed should drain completely in about 40 hours after the end of the rainfall. • Check to ensure that the filter surface does not clog after storm events.	After Rain Events
• Check the contributing drainage area, facility, inlets and outlets for debris. • Check to ensure that the filter surface is not clogging.	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, bulging, or cracking of concrete. • Inspect grates (perimeter sand filter). • Inspect inlets, outlets and overflow spillway to ensure good condition and no evidence of erosion. • Check to see if stormwater flow is bypassing the facility. • Ensure that no noticeable odors are detected outside the facility.	Annually
Maintenance Activities	**Suggested Schedule**
• Mow and stabilize (prevent erosion, vegetate denuded areas) the area draining to the sand filter. Collect and remove grass clippings. Remove trash and debris. • 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. • Repair or replace any damaged structural parts. • Stabilize any eroded areas.	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

The local jurisdiction encourages the use of the inspection checklist that is presented on the next page to guide the property owner in the inspection and maintenance of sand filters. The local jurisdiction can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the sand filter. Questions regarding stormwater facility inspection and maintenance should be referred to the local jurisdiction.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
SURFACE SAND FILTER INSPECTION CHECKLIST

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: __________ Time: _____________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Sand Filter Inspection List		
Complete drainage of the filter in about 40 hours after a rain event?		
Clogging of filter surface?		
Clogging of inlet/outlet structures?		
Clogging of filter fabric?		
Filter clear of debris and functional?		
Leaks or seeps in filter?		
Obstructions of spillway(s)?		
Animal burrows in filter?		
Sediment accumulation in filter bed (less than 50% is acceptable)?		
Cracking, spalling, bulging or deterioration of concrete?		
Erosion in area draining to sand filter?		
Erosion around inlets, filter bed, or outlets?		
Pipes and other structures in good condition?		
Undesirable vegetation growth?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

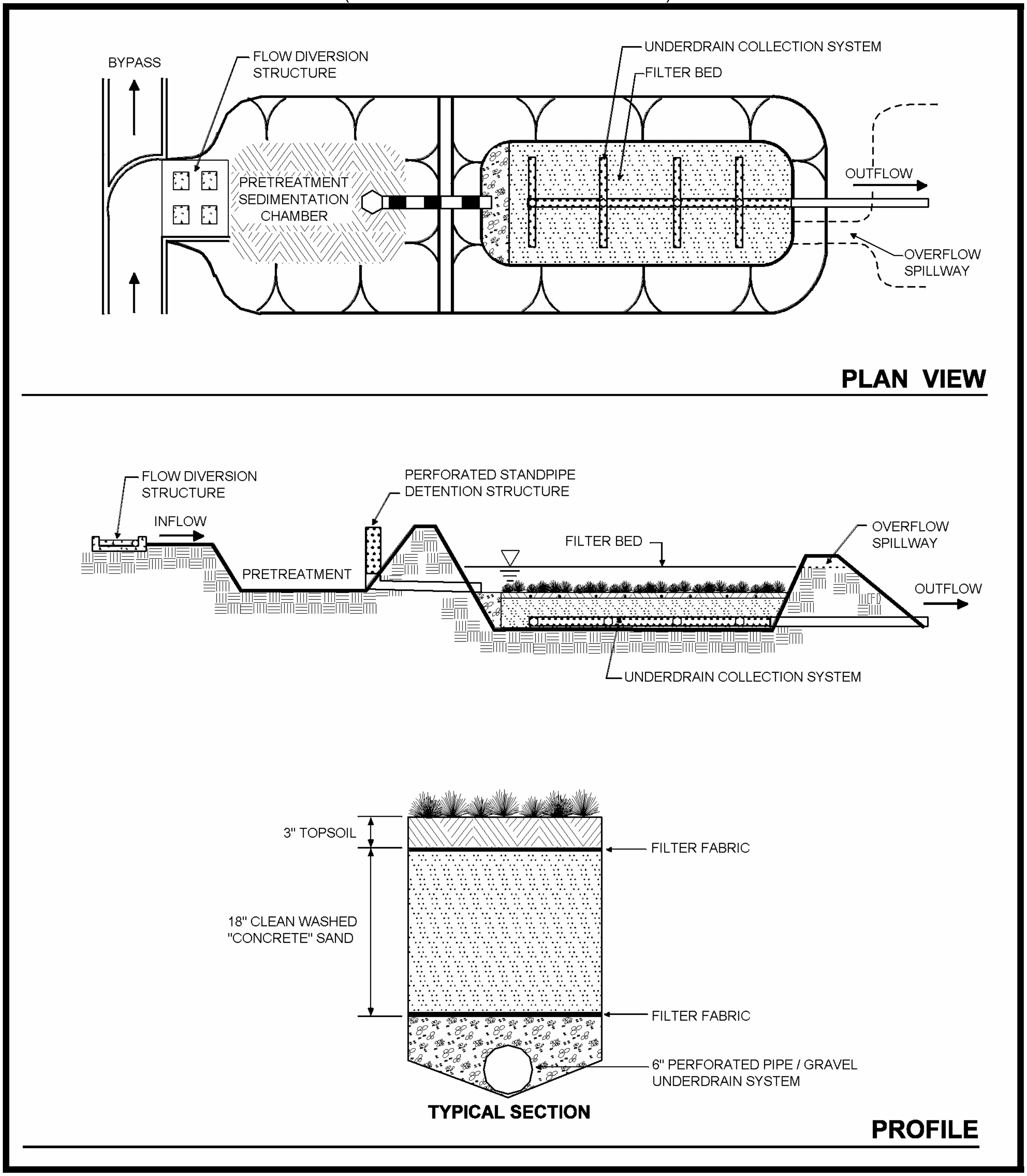
If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:_______________________________ Inspector Name (printed)___________________________

4.3.6.8 Example Schematic

Figure 4-35. Schematic of a Surface Sand Filter
(Source: Center for Watershed Protection)



4.3.6.9 Design Form

The local jurisdiction recommends the use of the following design procedure forms when designing sand filters. Proper use and completion of the form may allow a faster review of the Water Quality Management Plan by the local jurisdiction.

Design Procedure Forms: Sand Filters

PRELIMINARY HYDROLOGIC CALCULATIONS	
1a. Compute WQv volume requirements	
Compute Runoff Coefficient, Rv	Rv = ________
Compute WQv	WQv = ________ acre-ft
1b. Compute CPv	CPv = ________ acre-ft
SAND FILTER DESIGN	
2. Is the use of a sand filter appropriate?	Low point in development area = ________
	Low point at stream invert = ________
	Total available head = ________
	Average depth, h_f = ________
	See subsections 4.3.6.4 and 4.3.6.5 - A
3. Confirm design criteria and applicability.	***See subsection 4.3.6.5 - J***
4. Compute WQv peak discharge (Q_{wq})	
Compute Curve Number	CN = ________
Compute Time of Concentration, t_c	t_c = ________ hour
Compute Q_{wq}	Q_{wq} = ________ cfs
5. Size flow diversion structure	
Low flow orifice - orifice equation	A = ________ ft^2
	diameter = ________ in
	length = ________ ft
Overflow weir - Weir equation	
6. Size filtration bed chamber	
Compute area from Darcy's Law	A_f = ________ ft^2
Using length to width (2:1) ratio	L = ________ ft
	W = ________ ft
7. Size sedimentation chamber	
Compute area from Camp-Hazen equation	A_s = ________ ft^2
Given W from step 5, compute Length	L = ________
8. Compute V_{min}	V_{min} = ________ ft^3

Design Procedure Form: Sand Filters (continued)

9. Compute volume within practice	
Surface Sand Filter	
Volume within filter bed	V_f = ________ ft^3
Temporary storage above filter bed	V_{f-temp} = ________ ft3
Sedimentation chamber (remaining volume)	V_s = ________ ft3
Height in sedimentation chamber	h_s = ________ ft
Perforated stand pipe - orfice equation	A = ________ ft^2
	diameter = ________ in
Perimeter Sand Filter	
Compute volume in filter bed	V_f = ________ ft^3
Compute wet pool storage	V_w = ________ ft^3
Compute temporary storage	V_{f-temp} = ________ ft^3
	h_{temp} = ________ ft
10. Compute overflow weir sizes	
Compute overflow - Orifice equation	Q = ________ cfs
Weir from sedimentation chamber - Weir equation	Length = ________ ft
Weir from filtration chamber - Weir equation	Length = ________ ft
11. Verify peak flow control, water quality drawdown time and channel protection detention time	

4.3.6.10 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center, Accessed July 2005. *www.stormwatercenter.net*.

City of Knoxville. *Knoxville Best Management Practices Manual.* City of Knoxville Stormwater Engineering Division, March 2003.

City of Nashville, Tennessee. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

Connecticut Department of Environmental Protection. *Stormwater Quality Manual.* 2004.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

Minnesota Pollution Control Agency. *Minnesota Stormwater Manual.* Accessed January 2006. http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html

New Jersey Department of Environmental Protection. *Stormwater BMP Manual.* 2004.

StormwaterAuthority.com. *Sand and Organic Filters.* Accessed January 2006. www.stormwaterauthority.com

4.3.6.11 Suggested Reading

Bell, W., L. Stokes, L.J. Gavan, and T. Nguyen. *Assessment of the Pollutant Removal Efficiencies of Delaware Sand Filter BMPs.* City of Alexandria, Department of Transportation and Environmental Services, Alexandria, VA, 1995.

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks,* 1993.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Horner, R.R., and C.R. Horner. *Design, Construction, and Evaluation of a Sand Filter Stormwater Treatment System. Part II: Performance Monitoring.* Report to Alaska Marine Lines, Seattle, WA, 1995.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

Northern Virginia Regional Commission (NVRC). *The Northern Virginia BMP Handbook.* Annandale, VA, 1992.

Schueler, T.R. *Developments in Sand Filter Technology to Improve Stormwater Runoff Quality.* Watershed Protection Techniques 1(2):47-54, 1994.

US EPA. *Storm Water Technology Fact Sheet: Sand Filters. EPA 832-F-99-007.* Office of Water. 1999.

Young, G.K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. *Evaluation and Management of Highway Runoff Water Quality.* FHWA-PD-96-032. Federal Highway Administration, Office of Environment and Planning, 1996.

4.3.7 Infiltration Trench

**General Application
Water Quality BMP**

Description: An infiltration trench is an excavated trench filled with stone aggregate used to capture and allow infiltration of stormwater runoff into the surrounding soils from the bottom and sides of the trench.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Soil infiltration rate of 0.5 in/hr or greater required.
- Excavated trench (3 to 8 foot depth) filled with stone media (1.5- to 2.5-inch diameter)**;** pea gravel and sand filter layers.
- A sediment forebay and grass channel, or equivalent upstream pretreatment, must be provided.
- Observation well to monitor percolation.
- Size of drainage area.
- Maximum contributing drainage area of 5 acres.
- Must not be placed under pavement or concrete.

ADVANTAGES / BENEFITS:

- Provides for groundwater recharge.
- Good for small sites with porous soils.

DISADVANTAGES / LIMITATIONS:

- Potential for groundwater contamination.
- High clogging potential; should not be used on sites with fine-particle soils (clays or silts) in drainage area.
- Significant setback requirements.
- Restrictions in karst areas.
- Geotechnical testing required; two borings per facility.

MAINTENANCE REQUIREMENTS:

- Inspect for clogging.
- Remove sediment from forebay.
- Replace pea gravel layer as needed.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	✷
Detention/Retention:	**No**

✷ in certain situations

Accepts hotspot runoff: *No*

COST CONSIDERATIONS

Land Requirement:	**Med**
Capital Cost:	**High**
Maintenance Burden:	**High**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

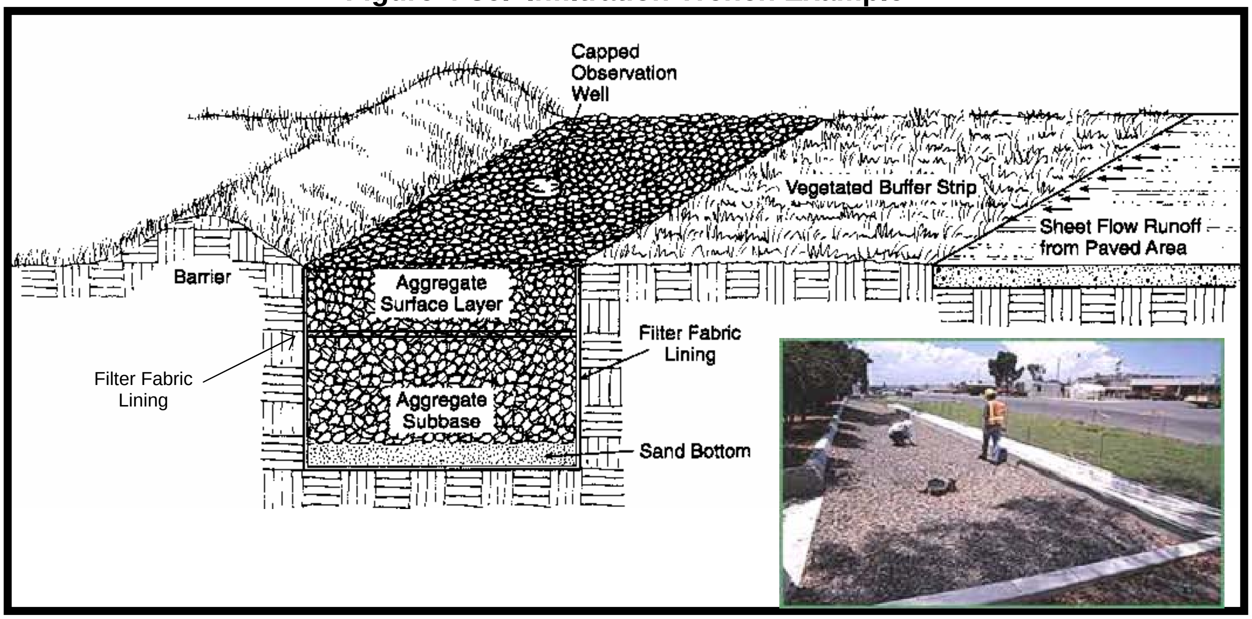
Total Suspended Solids:	**90%**

4.3.7.1 General Description

Infiltration trenches are excavations typically filled with stone to create an underground reservoir for stormwater runoff (see Figure 4-36). This runoff volume gradually infiltrates through the bottom and sides of the trench into the subsoil over a 2-day period and eventually reaches the water table. By diverting runoff into the soil, an infiltration trench not only treats the water quality volume, but also helps to preserve the natural water balance on a site and can recharge groundwater and preserve baseflow. Due to this fact, infiltration systems are limited to areas with highly porous soils where the water table and/or bedrock are located well below the bottom of the trench. In addition, infiltration trenches must be carefully sited to avoid the potential of groundwater contamination.

Infiltration trenches are not intended to trap sediment and must always be designed with a sediment forebay and grass channel or filter strip, or other appropriate pretreatment measures to prevent clogging and failure. Due to their high potential for failure, these facilities must only be considered for sites where upstream sediment control can be ensured.

Figure 4-36. Infiltration Trench Example



4.3.7.2 Stormwater Management Suitability

Infiltration trenches are designed primarily for stormwater quality. However, they can provide limited runoff quantity control, particularly for smaller storm events. For some smaller sites, trenches can be designed to capture and infiltrate the channel protection volume (CPv) in addition to the water quality volume (WQv). An infiltration trench will need to be used in conjunction with another structural BMP to provide flood protection from locally regulated peak discharges, if required.

<u>Water Quality (WQv)</u>
Using the natural filtering properties of soil, infiltration trenches can remove a wide variety of pollutants from stormwater through sorption, percolation, filtering, and bacterial and chemical degradation. Sediment load and other suspended solids are removed from runoff by pretreatment measures in the facility that treats flows before they reach the trench surface.

<u>Channel Protection (CPv)</u>
For smaller sites, an infiltration trench may be designed to capture and infiltrate the entire CPv in either an off or on-line configuration. For larger sites, or where only the WQv is diverted to the trench, another structural BMP must be used to provide CPv extended detention.

4.3.7.3 Pollutant Removal Capabilities

An infiltration trench is presumed to be able to remove 90% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. The TSS removal performance is reduced for undersized, poorly designed, or unmaintained infiltration trenches.

The total suspended solids design pollutant removal rate of 90% is a conservative average pollutant reduction percentage for design derived from sampling data, modeling and professional judgment.

For additional information and data on pollutant removal capabilities for infiltration trenches, see the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the International Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

4.3.7.4 Application and Site Feasibility Criteria

Infiltration trenches are generally suited for medium-to-high density residential and commercial developments where the subsoil is sufficiently permeable to provide a reasonable infiltration rate and the water table is low enough to prevent groundwater contamination. They are applicable primarily for impervious areas where there are not high levels of fine particulates (clay/silt soils) in the runoff and should only be considered for sites where the sediment load is relatively low.

Infiltration trenches can either be used to capture sheet flow from a drainage area or function as an off-line device. Due to the relatively narrow shape, infiltration trenches can be adapted to many different types of sites and can be utilized in retrofit situations. Unlike some other structural stormwater BMPs, they can easily fit into the margin, perimeter, or other unused areas of developed sites.

To protect groundwater from potential contamination, infiltration trenches cannot be utilized to treat runoff from hotspot land uses or activities, as identified by the local jurisdiction. For example, infiltration trenches should not be used for manufacturing and industrial sites, where there is a potential for high concentrations of soluble pollutants and heavy metals, or for areas that may have a high pesticide concentration. Infiltration trenches are also not suitable in areas with karst geology without adequate geotechnical testing by qualified individuals.

The following criteria should be evaluated to ensure the suitability of an infiltration trench for meeting stormwater management objectives on a site or development.

<u>General Feasibility</u>

- Suitable for use in a residential subdivision
- Suitable for use in high density/ultra-urban areas
- Not suitable for use as a regional (i.e., off-site or treating more than one site) stormwater control

<u>Physical Feasibility - Physical Constraints at Project Site</u>

- <u>Drainage Area</u> – 5 acres maximum
- <u>Space Required</u> – Will vary depending on the depth of the facility
- <u>Site Slope</u> – No more than 6% slope (for pre-construction facility footprint) across the location of the infiltration trench
- <u>Minimum Head</u> – Elevation difference needed from the inflow of the infiltration trench to the outflow: 1 foot
- <u>Minimum Depth to Water Table</u> – 4 feet recommended between the bottom of the infiltration trench and the elevation of the seasonally high water table
- <u>Soils</u> – Infiltration rate greater than 0.5 inches per hour required (typically hydrologic group “A”, some group “B” soils)

Other Constraints/Considerations

- Wellhead Protection – Reduce potential groundwater contamination (in required wellhead protection areas) by preventing infiltration of hotspot runoff. May require liner for type "A" and "B" soils; pretreat hotspots; provide 2 to 4 foot separation distance from water table.

4.3.7.5 Planning and Design Standards

The following standards are to be considered **minimum** standards for the design of an infiltration trench facility. Consult with the local jurisdiction to determine if there are any variations to these criteria or additional standards that must be followed.

A. CONSTRUCTION SEQUENCING

- Ideally, the construction of an infiltration trench shall take place **after** the construction site has been stabilized.
- In the event that the infiltration trench is not constructed after stabilization, care shall be taken during construction to minimize the risk of premature failing of the infiltrations trench due to deposition of sediments from disturbed, unstabilized areas.
- Diversion berms and erosion prevention and sediment controls shall be maintained around an infiltration trench during all phases of construction. No runoff or sediment shall enter the infiltration trench area prior to completion of construction and the complete stabilization of construction areas.
- Infiltration may be used as a temporary sediment trap for construction activities if all accumulated sediment is removed prior to media placement.
- During and after excavation of the infiltration trench, all excavated materials shall be placed downstream, away from the trench, to prevent redeposit of the material during runoff events.

B. LOCATION AND SITING

- To be suitable for infiltration, underlying soils should have an infiltration rate (f_c) of 0.5 inches per hour or greater, as initially determined from NRCS soil textural classification, and subsequently confirmed by field geotechnical tests. The minimum geotechnical testing is one test hole per 5,000 square feet, with a minimum of two borings per facility (taken within the proposed limits of the facility). Infiltration trenches cannot be used in fill soils.
- Heavy equipment shall not be utilized in the area where the infiltration trench will be located. Soil compaction will adversely affect the performance of the trench. Infiltration trench sites should be roped-off and flagged during construction.
- During excavation and trench construction, only light equipment such as backhoes or wheel and ladder type trenchers should be used to minimize compaction of surrounding soils.
- Infiltration trenches should have a contributing drainage area of 5 acres or less.
- Soils on the drainage area tributary to an infiltration trench should have a clay content of less than 20% and a silt/clay content of less than 40% to prevent clogging and failure.
- There should be at least 4 feet between the bottom of the infiltration trench and the elevation of the seasonally high water table.
- Clay lenses, bedrock or other restrictive layers below the bottom of the trench will reduce infiltration rates unless excavated.
- Each infiltration trench shall be placed in an easement that is recorded with the deed. The easement shall be defined at the outer edge of the infiltration trench. Minimum setback requirements for the easement shall be as follows unless otherwise specified by the local jurisdiction:
  - From a building foundation – 25 feet
  - From a private well – 100 feet

- ➢ From a public water supply well – 1,200 feet
- ➢ From a septic system tank/leach field – 100 feet
- ➢ From surface waters – 100 feet
- ➢ From surface drinking water sources – 400 feet (100 feet for a tributary)

- When used in an off-line configuration, the water quality volume (WQv) is diverted to the infiltration trench through the use of a flow splitter. Stormwater flows greater than the WQv are diverted to other controls or downstream using a diversion structure or flow splitter.
- To reduce the potential for costly maintenance and/or system reconstruction, it is strongly recommended that the trench be located in an open or lawn area, with the top of the structure as close to the ground surface as possible. Infiltration trenches shall not be located beneath paved surfaces, such as parking lots.
- Infiltration trenches are designed for intermittent flow and must be allowed to drain and allow reaeration of the surrounding soil between rainfall events. They must not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.

C. GENERAL DESIGN

- A well-designed infiltration trench consists of:
  (1) Excavated shallow trench backfilled with sand, coarse stone, and pea gravel, and lined with a filter fabric bottom and an additional layer of filter fabric 1' from the top of gravel to allow easy cleanout of clogged stone;
  (2) Appropriate pretreatment measures; and
  (3) One or more observation wells to show how quickly the trench dewaters or to determine if the device is clogged.

Figure 4-37 provides a plan view and profile schematic for the design of an off-line infiltration trench facility. An example of an observation well is shown in Figure 4-38.

D. PHYSICAL SPECIFICATIONS / GEOMETRY

- The required trench storage volume is equal to the water quality volume (WQv). For smaller sites, an infiltration trench can be designed with a larger storage volume to include the channel protection volume (CPv).
- A trench must be designed to fully dewater the entire WQv within 24 to 48 hours after a rainfall event. The slowest infiltration rate obtained from tests performed at the site should be used in the design calculations.
- Trench depths should be between 3 and 8 feet, to provide for easier maintenance. The width of a trench must be less than 25 feet.
- Broad, shallow trenches reduce the risk of clogging by spreading the flow over a larger area for infiltration.
- The surface area required is calculated based on the trench depth, soil infiltration rate, aggregate void space, and fill time (assume a fill time of 2 hours for most designs).
- The bottom slope of a trench should be flat across its length and width to evenly distribute flows, encourage uniform infiltration through the bottom, and reduce the risk of clogging.
- The stone aggregate used in the trench should be washed, bank-run gravel, 1.5 to 2.5 inches in diameter with a void space of about 40%. Aggregate contaminated with soil shall not be used. A porosity value (void space/total volume) of 0.32 should be used in calculations, unless aggregate specific data exist.
- A 6-inch layer of clean, washed sand is placed on the bottom of the trench to encourage drainage and prevent compaction of the native soil while the stone aggregate is added.

- The infiltration trench is lined on the sides and top by an appropriate geotextile filter fabric that prevents soil piping but has greater permeability than the parent soil. The top layer of filter fabric is located 2 to 6 inches from the top of the trench and serves to prevent sediment from passing into the stone aggregate. Since this top layer serves as a sediment barrier, it will need to be replaced more frequently and must be readily separated from the side sections.
- The top surface of the infiltration trench above the filter fabric is typically covered with pea gravel. The pea gravel layer improves sediment filtering and maximizes the pollutant removal in the top of the trench. In addition, it can easily be removed and replaced should the device begin to clog. Alternatively, the trench can be covered with permeable topsoil and planted with grass in a landscaped area.
- An observation well must be installed in every infiltration trench and should consist of a perforated PVC pipe, 4 to 6 inches in diameter, extending to the bottom of the trench. The observation well will show the rate of dewatering after a storm, as well as provide a means of determining sediment levels at the bottom and when the filter fabric at the top is clogged and maintenance is needed. It should be installed along the centerline of the structure, flush with the ground elevation of the trench. A visible floating marker should be provided to indicate the water level. The top of the well should be capped and locked to discourage vandalism and tampering.
- The trench excavation should be limited to the width and depth specified in the design. Excavated material should be placed away from the open trench so as not to jeopardize the stability of the trench sidewalls. The bottom of the excavated trench shall not be loaded in a way that causes soil compaction, and should be scarified prior to placement of sand. The sides of the trench shall be trimmed of all large roots. The sidewalls shall be uniform with no voids and scarified prior to backfilling. All infiltration trench facilities should be protected during site construction and should be constructed after upstream areas have been stabilized.
- Smearing of the soil at its interface with the trench bottom or sides must be avoided or corrected. Smearing can be corrected by raking or roto-tilling.

E. PRETREATMENT / INLETS

- Pretreatment facilities **must always** be used in conjunction with an infiltration trench to prevent clogging and failure.
- For a trench receiving sheet flow from an adjacent drainage area, the pretreatment system should consist of a vegetated filter strip with a minimum 25-foot length. A vegetated buffer strip around the entire trench is required if the facility is receiving runoff from both directions. If the infiltration rate for the underlying soils is greater than 2 inches per hour, 50% of the WQv should be pretreated by another method prior to reaching the infiltration trench.
- For an off-line configuration, pretreatment should consist of a sediment forebay, vault, plunge pool, or similar sedimentation chamber (with energy dissipaters) sized to 25% of the water quality volume (WQv). Exit velocities from the pretreatment chamber must be non-erosive for the 2-year design storm.

F. OUTLET STRUCTURES

- Outlet structures are not required for infiltration trenches.

G. EMERGENCY SPILLWAY

- Typically for off-line designs, there is no need for an emergency spillway. However, a non-erosive overflow channel should be provided to safely pass flows that exceed the storage capacity of the trench to a stabilized downstream area or watercourse.

H. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right-of-way or drainage easement shall be provide for an infiltration trench, from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles. Adequate access must be provided to the grates to the filter bed for perimeter sand filter design. Facility designs must enable maintenance personnel to easily remove and replace upper layers of the infiltration media.

I. SAFETY FEATURES

- In general, infiltration trenches are not likely to pose a physical threat to the public and do not need to be fenced.

J. LANDSCAPING

- Vegetated filter strips and buffers should fit into and blend with surrounding area. Native grasses are preferable, if compatible. The trench may be covered with permeable topsoil and planted with grass in a landscaped area

K. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

There are a number of additional site specific design criteria and issues (listed below) that must be considered in the design of an infiltration trench.

Physiographic Factors - Local terrain design constraints

- High Relief – Maximum site slope of 6%
- Karst – Not suitable without adequate geotechnical testing

Special Downstream Watershed Considerations

- Wellhead Protection – Reduce potential groundwater contamination (in required wellhead protection areas) by preventing infiltration of hotspot runoff. May require liner for type “A” and “B” soils; Pretreat hotspots; provide 2 to 4 foot separation distance from water table.

4.3.7.6 Design Procedures

Step 1. Compute runoff control volumes

Calculate WQv, CPv, and the locally regulated peak discharges, in accordance with the guidance presented in Chapter 3.

Step 2. Determine if the development site and conditions are appropriate for the use of an infiltration trench.

Consider the subsections 4.3.7.4 and 4.3.7.5-B (Location and Siting).

Step 3. Confirm design criteria and applicability

Consider any special site-specific design conditions/criteria from subsection 4.3.7.5-K (Additional Site-Specific Design Criteria and Issues).

Check with the local jurisdiction and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 4. Compute WQv peak discharge (Q_{wq})

The peak rate of discharge for water quality design storm is needed for sizing of off-line diversion (see Chapter 3 for more information).

Step 5. Size flow diversion structure, if needed

A flow regulator (or flow splitter diversion structure) should be supplied to divert the WQv to the infiltration trench.
Size low flow orifice, weir, or other device to pass Q_{wq}.

Step 6. Size infiltration trench

The area of the trench can be determined from the following equation:

$$A = \frac{WQv}{(nd + kT/12)}$$

where:

A	=	Surface Area
WQv	=	Water Quality Volume (or total volume to be infiltrated)
n	=	porosity
d	=	trench depth (feet)
k	=	percolation (inches/hour)
T	=	Fill Time (time for the practice to fill with water), in hours

A porosity value *n* = 0.32 should be used.

All infiltration systems should be designed to fully dewater the entire WQv within 24 to 48 hours after the rainfall event.

A fill time T=2 hours can be used for most designs.
See subsection 4.3.7.5-D (Physical Specifications/Geometry) for more specifications.

Step 7. Determine pretreatment volume and design pretreatment measures

Size pretreatment facility to treat 25% of the water quality volume (WQv) for off-line configurations. See subsection 4.3.7.5-E (Pretreatment / Inlets) for more details.

Step 8. Design spillway(s)

Adequate stormwater outfalls should be provided for the overflow exceeding the capacity of the trench, ensuring non-erosive velocities on the down-slope.

4.3.7.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.7.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of an infiltration trench as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local jurisdiction has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for infiltration trenches, along with a suggested frequency for each activity. Individual trenches may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e.., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the infiltration trench in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• A record should be kept of the dewatering time (i.e., the time required to drain the infiltration trench completely after a storm event) of the trench to determine if maintenance is necessary. The trench should drain completely in about 24 hours after the end of the rainfall. Ponded water inside the trench (as visible from the observation well or on the surface) longer than 24 hours or several days after a storm event is an indication that the trench is clogged.	After Rain Events
• Check that the area draining to the trench, the trench and its inlets are clear of debris. • Check the area draining to the trench for evidence of erosion.	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.	Semi-annual Inspection
Maintenance Activities	**Suggested Schedule**
• Remove sediment and oil/grease from pretreatment devices, as well as overflow structures. • Mow grass filter strips as necessary. Remove grass clippings.	Monthly
• 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). Removed sediment and media may usually be disposed of in a landfill. • Stabilize (i.e., vegetate or cover) areas of erosion in the area draining to the trench.	As needed
• Perform total rehabilitation of the trench to maintain design storage capacity. • Excavate trench walls to expose clean soil.	Upon Failure

The local jurisdiction encourages the use of the inspection checklist that is presented on the next page to guide the property owner in the inspection and maintenance of an infiltration trench. The local jurisdiction can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the trench. Questions regarding stormwater facility inspection and maintenance should be referred to the local jurisdiction.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
INFILTRATION TRENCH INSPECTION CHECKLIST

Location: ____ Owner Change since last inspection? Y N
Owner Name, Address, Phone: ____
Date: ___________ Time: ______________ Site conditions:__________________________________

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Inspection List		
Complete drainage of the filter in about 24 to 48 hours after a rain event?		
Clogging of trench surface?		
Clogging of inlet/outlet structures?		
Standing water in observation well when no water should be present?		
Trench clear of debris and functional?		
Evidence of leaks or seeps?		
Animal burrows in trench?		
Cracking, spalling, bulging or deterioration of concrete?		
Erosion in area draining to trench?		
Erosion around inlets, trench, or outlets?		
Pipes and other structures in good condition?		
Undesirable vegetation growth?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:_______________________ Inspector Name (printed)_____________________

4.3.7.8 Example Schematics

Figure 4-37. Schematic of an Infiltration Trench
(Source: Center for Watershed Protection)

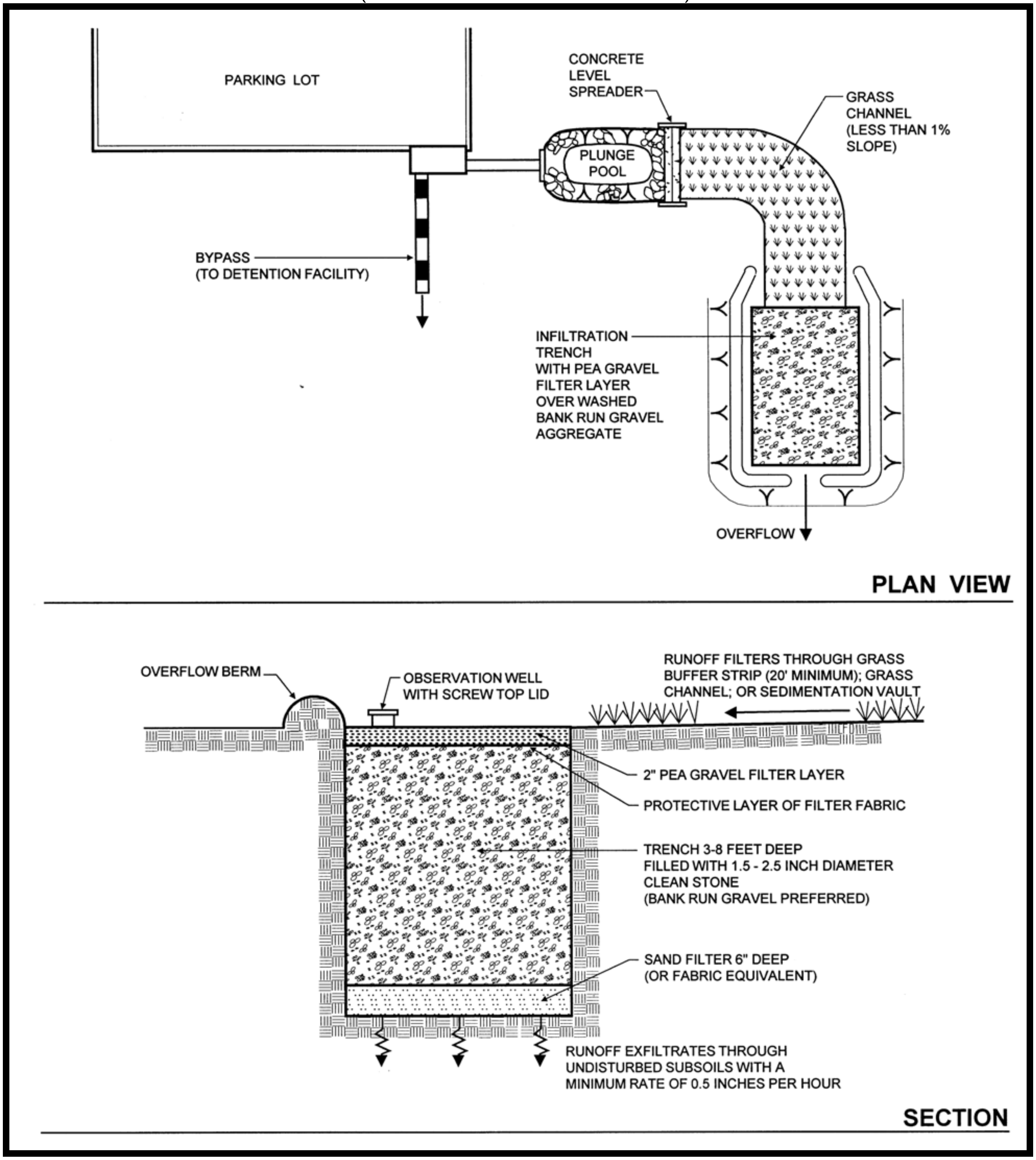
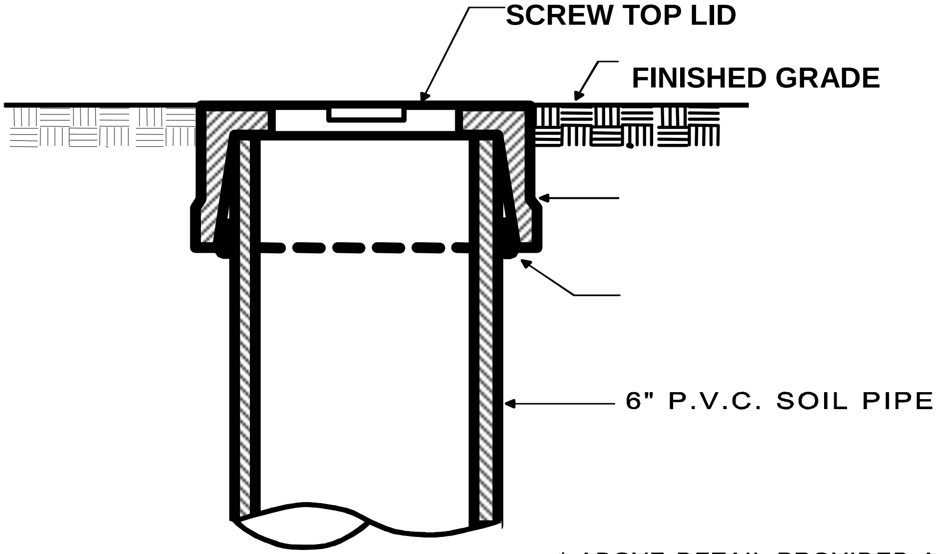


Figure 4-38. Observation Well Detail



* ABOVE DETAIL PROVIDED AS SCHEMATIC
SCREW TOP P.V.C. WELL CAP ONLY

EACH OBSERVATION WELL / CLEANOUT SHALL INCLUDE THE FOLLOWING:

1. FOR AN UNDERGROUND FLUSH MOUNTED OBSERVATION WELL / CLEANOUT, PROVIDE A TUBE MADE OF NON-CORROSIVE MATERIAL, SCHEDULE 40 OR EQUAL, AT LEAST THREE FEET LONG WITH AN INSIDE DIAMETER OF AT LEAST 6 INCHES.

2. THE TUBE SHALL HAVE A FACTORY ATTACHED CAST IRON OR HIGH IMPACT PLASTIC COLLAR WITH RIBS TO PREVENT ROTATION WHEN REMOVING SCREW TOP LID. THE SCREW TOP LID SHALL BE CAST IRON OR HIGH IMPACT PLASTIC THAT WILL WITHSTAND ULTRA-VIOLET RAYS.

4.3.7.9 Design Form

The local jurisdiction recommends the use of the following design procedure forms when designing infiltration trenches. Proper use and completion of the form may allow a faster review of the Water Quality Management Plan by the local jurisdiction.

Design Procedure Form: Infiltration Trench

PRELIMINARY HYDROLOGIC CALCULATIONS	
1a. Compute WQv volume requirements	
Compute Runoff Coefficient, R_v	Rv = ________
Compute WQv	WQv = ________ acre-ft
1b. Compute CPv	CPv = ________ acre-ft
INFILTRATION TRENCH DESIGN	
2. Is the use of an infiltration trench appropriate?	***See subsections 4.3.7.4 and 4.3.7.5 - B***
3. Confirm local design criteria and applicability.	***See subsection 4.3.7.5 - K***
4. Compute WQv peak discharge (Q_{wq})	
Compute Curve Number	CN = ________
Compute Time of Concentration t_c	t_c = ________ hour
Compute Q_{wq}	Q_{wq} = ________ cfs
5. Size infiltration trench	Area = ________ ft^2
Width must be less than 25 ft	Width = ________ ft
	Length = ________ ft
6. Size the flow diversion structures	
Low flow orifice from orifice equation	
$Q = CA(2gh)^{0.5}$	A = ________ ft^2
C varies with orifice condition	diam. = ________ inch
Overflow weir from weir equation	
$Q = CLH^{3/2}$	Length = ________ ft
7. Pretreatment volume (for offine designs)	
$Vol_{pre} = 0.25(WQv)$	Vol_{pre} = ________ ft^3
8. Design spillway(s)	
9. Verify peak flow control, water quality drawdown time and channel protection detention time	

4.3.7.10 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center, Accessed July 2005. *www.stormwatercenter.net*.

City of Nashville, Tennessee. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

Federal Highway Administration (FHWA). *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring.* United States Department of Transportation, Accessed January 2006. http://www.fhwa.dot.gov/environment/ultraurb/index.htm

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

4.3.7.11 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

US EPA. *Storm Water Technology Fact Sheet: Storm Water Wetlands.* EPA 832-F-99-025. Office of Water, 1999.

Faulkner, S. and C. Richardson. *Physical and Chemical Characteristics of Freshwater Wetland Soils.* Constructed Wetlands for Wastewater Treatment, ed. D. Hammer, Lewis Publishers, 831 pp, 1991.

Guntenspergen, G.R., F. Stearns, and J. A. Kadlec. *Wetland Vegetation.* Constructed Wetlands for Wastewater Treatment, ed. D. A. Hammer, Lewis Publishers, 1991.

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

4.3.8 Enhanced Swales

**General Application
Water Quality BMP**

Description: Enhanced swales are vegetated open channels that are explicitly designed and constructed to capture and treat stormwater runoff within dry or wet cells formed by check dams or other means.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Maximum contributing drainage area of 5 acres.
- Longitudinal slopes must be less than 4%.
- Bottom width of 2 to 8 feet.
- Side slopes 2:1 or flatter; 4:1 recommended.
- Convey the 25-year storm event with a minimum of 6 inches of freeboard.
- No soil restrictions.
- Dry swales require a permeable soil layer.
- Wet swales require wetland plants.

ADVANTAGES / BENEFITS:

- Combines stormwater treatment with runoff conveyance system.
- Less expensive than curb and gutter.
- Reduces runoff velocity and the potential for channel/ditch erosion.

DISADVANTAGES / LIMITATIONS:

- Higher maintenance than curb and gutter.
- Cannot be used on steep slopes.
- Possible resuspension of sediment.
- Potential for odor / mosquitoes (wet swale).

MAINTENANCE REQUIREMENTS:

- Maintain grass heights of approximately 4 to 6 inches (dry swale).
- Occasional sediment removal from forebay and channel.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	✷
Detention/Retention:	**No**

✷ in certain situations

Accepts hotspot runoff: *Yes (requires impermeable liner)*

COST CONSIDERATIONS

Land Requirement:	**High**
Capital Cost:	**Med**
Maintenance Burden:	**Low**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**No**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids (dry swale):	**90%**
Total Suspended Solids (wet swale):	**75%**

4.3.8.1 General Description

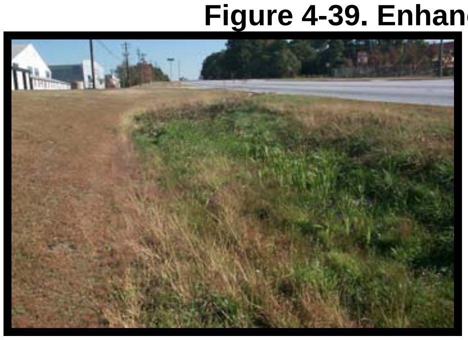
Enhanced swales (also referred to as *vegetated open channels* or *water quality swales*) are conveyance channels engineered to capture and treat the water quality volume (WQv) for a drainage area. They differ from a normal drainage channel or conventional swale because they incorporate specific features that enhance stormwater pollutant removal effectiveness.

Enhanced swales are designed with limited longitudinal slopes to force the stormwater flow to be slow and shallow, thus allowing for particulates to settle and limiting the effects of erosion. Berms and/or check dams installed perpendicular to the flow path promote settling and infiltration.

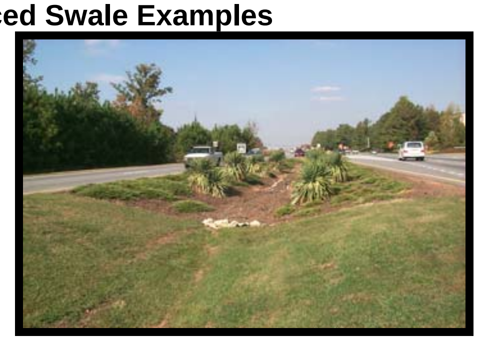
There are two primary enhanced swale designs, the *dry swale* and the *wet swale* (or *wetland channel*). Figure 4-39 illustrates each design. Below are descriptions of these two designs:

- **Dry Swale** – The dry swale is a vegetated conveyance channel designed to include a filter bed of prepared soil that overlays an underdrain system. Dry swales are sized to allow the entire WQv to be filtered or infiltrated through the bottom of the swale. Because they are dry most of the time, they are often the preferred option in residential settings.
- **Wet Swale (Wetland Channel)** – The wet swale is a vegetated channel designed to retain water or marshy conditions that support wetland vegetation. A high water table or poorly drained soils are necessary to retain water. The wet swale essentially acts as a linear shallow wetland treatment system, where the WQv is retained.

Figure 4-39. Enhanced Swale Examples



Enhanced Dry Swale



Enhanced Wet Swale

Enhanced swales must not to be confused with a *filter strip* or *grass channel*, because they afford a much higher level of water quality treatment than the latter BMPs. Ordinary *grass channels* are not engineered to provide the same treatment capability as a well-designed dry swale with filter media. *Filter strips* are designed to accommodate overland flow rather than channelized flow and can be used as stormwater reductions to help reduce the total water quality treatment volume for a site. Both of these practices may be used for pretreatment or included in a "treatment train" approach where redundant treatment is provided. Please see a further discussion of these structural controls in subsections 4.3.9 and 4.3.10, respectively.

4.3.8.2 Stormwater Management Suitability

Enhanced swale systems are designed primarily for stormwater quality and have only a limited ability to provide channel protection or flood protection.

<u>Water Quality (WQv) and Channel Protection (CPv)</u>
Dry swale systems rely primarily on filtration through an engineered media to provide removal of stormwater contaminants. Wet swales achieve pollutant removal both from sediment accumulation and biological removal. Generally only the WQv is treated by a dry or wet swale, and another structural BMP must be used to provide extended detention of the CPv. However, for some smaller sites, a swale may be designed to capture and detain the full CPv.

4.3.8.3 Pollutant Removal Capabilities

The dry enhanced swale is presumed to be able to remove 90% of the TSS load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. The TSS removal value for wet swales is 75%. Undersized or poorly designed swales can reduce TSS removal performance.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment. In a situation where a removal rate is not deemed sufficient, additional controls may be put in place at the given site in a series or "treatment train" approach.

- Total Suspended Solids – Dry Swale 90% / Wet Swale 75%

For additional information and data on pollutant removal capabilities for enhanced dry and wet swales, see the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the International Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

4.3.8.4 Application and Feasibility Criteria

Enhanced swales can be used in a variety of development types; however, they are primarily applicable to residential and commercial areas of low to moderate density where the impervious cover in the contributing drainage area is relatively small, and along roads and highways. Dry swales are mainly used in moderate to large lot residential developments, small impervious areas (parking lots and rooftops), and along rural highways. Wet swales tend to be used for highway runoff applications, small parking areas, and in commercial developments as part of a landscaped area.

Because of their relatively large land requirement, enhanced swales are generally not used in higher density areas. In addition, wet swales may not be desirable for some residential applications, due to the presence of standing and stagnant water, which may create nuisance odor or mosquito problems.

The topography and soils of a site will determine the applicability of one of the two enhanced swale designs. Overall, the topography should allow for the design of a swale with sufficient slope and cross-sectional area to maintain non-erosive velocities. The following criteria should be evaluated to ensure the suitability of a stormwater basin for meeting stormwater management objectives on a site or development.

General Feasibility

- Suitable for use in residential subdivisions and in non-residential areas.
- Not generally suitable for high density/ultra-urban areas, as land requirements may preclude their use.
- Not suitable for use as a regional stormwater control.

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – 5 acres maximum
- Space Required – Approximately 10 to 20% of the tributary impervious area
- Channel Slope – Channel slope shall not exceed 4%
- Minimum Head – Elevation difference needed at a site from the inflow to the outflow: 3 to 5 feet for dry swale; 1 foot for wet swale
- Minimum Depth to Water Table – 2 feet required between the bottom of a dry swale and the elevation of the seasonally high water table, if an aquifer or treating a stormwater discharging from a hotspot land use; wet swale is below water table or placed in poorly drained soils
- Soils – Engineered media for dry swale

Other Constraints / Considerations

- Aquifer Protection – Exfiltration from the enhanced swale should be prevented in enhanced swales that serve hotspot land uses.

4.3.8.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of an enhanced swale. Enhanced swales that are not designed to these standards will not be approved. The local jurisdiction shall have the authority to require additional design conditions if deemed necessary.

A. LOCATION AND SITING

- A dry or wet swale shall be located on a property such that the topography allows for the design of a channel with sufficiently mild slope, as discussed in part C below (unless small drop structures are used), and sufficient cross-sectional area to maintain non-erosive velocities. Site designers shall also take into account the location and use of other site features, such as buffers and undisturbed natural areas when determining the location of an enhanced swale, and should attempt to aesthetically “fit” the facility into the landscape.
- Enhanced swale systems shall have a contributing drainage area of 5 acres or less.
- A wet swale shall only be used where the water table is at or near the soil surface, or where there is a sufficient water balance in poorly drained soils to support a wetland plant community.
- Each enhanced swale shall be placed in an easement that is recorded with the deed. The easement shall be defined from the centerline of the grass channel to the same width as that specified for stormwater pipes in the local regulations.

B. GENERAL DESIGN

- Enhanced swales that are located “on-line” shall also be designed to safely pass larger flows in accordance with the local jurisdiction’s design criteria for open channels (Chapter 2). Flow enters the channel through a pretreatment forebay. Runoff can also enter along the sides of the channel as sheet flow through the use of a pea gravel flow spreader trench located along the top of the bank of the swale.

Dry Swale

- A dry swale system shall consist of an open conveyance channel with a filter bed of permeable soils that overlay an underdrain system. Flow passes into and is detained in the main portion of the channel where it is filtered through the soil bed. Runoff is collected and conveyed by a perforated pipe and gravel underdrain system to the outlet. Figure 4-40 presented at the end of this section provides a plan view and profile schematic for the design of a dry swale system.

Wet Swale

- A wet swale or wetland channel shall consist of an open conveyance channel which has been excavated to the water table or to poorly drained soils. Check dams are used to create multiple wetland “cells,” which act as miniature shallow marshes. Figure 4-41 presented at the end of this section provides a plan view and profile schematic for the design of a wet swale system.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

General

- The enhanced swale shall have a minimum slope of 1%, and the slope shall not exceed 4%. A 1% to 2% slope is considered ideal. Where topography necessitates a slope steeper than 2%, 6 to 12-inch drop structures must be designed and constructed to limit the energy slope to within the recommended 1 to 2% range. Energy dissipation is required below the drops. The drops shall be spaced a minimum of 50 feet apart.

- The maximum WQv ponding depth in the enhanced swale shall not exceed 18 inches at the end point of the swale. An average depth of 12-inches shall be maintained.
- Enhanced swales shall have a bottom width ranging from 2 to 8 feet to ensure adequate filtration. Wider channels will be permitted, but must contain berms, walls, or a compound cross-section to prevent channel braiding or uncontrolled sub-channel formation.
- Enhanced swales shall have a trapezoidal or compound cross-section. Side slopes shall not exceed 2:1. The local jurisdiction may approve side slopes up to 4:1 where side inflows by sheet flow will not be substantial, and where such swales can be easily maintained. Side slopes greater than 2:1 in residential areas are strongly discouraged.
- Enhanced swales shall be designed such that the peak velocity for the 2-year storm must be conveyed in a non-erosive manner, given the soil and vegetative cover provided.
- If the enhanced swale is on-line, the swale shall be sized to convey runoff for the locally regulated peak discharge.

Dry Swale

- Dry swale channels shall be sized to store and infiltrate the entire water quality volume (WQv) with less than 18 inches of ponding and allow for full filtering through the permeable soil layer. Ponding shall occur for no longer than 48 hours, though a 24-hour ponding time is more desirable.
- The bed of a dry swale shall consist of a permeable soil layer of at least 30 inches in depth, above a 4-inch diameter perforated longitudinal underdrain (PVC AASHTO M 252, HDPE or other suitable underdrain pipe material) in a 6-inch gravel layer. The soil media shall have an infiltration rate of at least 1 foot per day (1.5 feet per day maximum) and contain a high level of organic material to facilitate pollutant removal. A permeable filter fabric shall be placed between the gravel layer and the overlying soil.
- Excavation of the dry swale and its associated underdrain shall be limited to the width and depth specified in the design. The bottom of the excavated trench shall not be loaded in a way that causes soil compaction, and shall be scarified prior to placement of gravel and permeable soil. The sides of the channel shall be trimmed of all large roots. The sidewalls shall be uniform with no voids and scarified prior to backfilling.

Wet Swale

- Wet swale channels are sized to retain the entire water quality volume (WQv) with less than 18 inches of ponding at the maximum depth point.
- Check dams can be used to achieve multiple wetland cells. V-notch weirs in the check dams can be utilized to direct low flow volumes.

D. PRETREATMENT / INLETS

- Inlets to enhanced swales shall include energy dissipators, such as riprap.
- Pretreatment of runoff in both a dry and wet swale system shall be provided by a sediment forebay located at the inlet. The pretreatment volume shall be equal to 0.1 inches per impervious acre (363 ft^3). This storage can be obtained by providing check dams at pipe inlets and/or driveway crossings.
- Enhanced swale systems that receive direct concentrated runoff (as opposed to shallow concentrated or overland flow) shall have a 6-inch drop to a pea gravel diaphragm flow spreader at the upstream end of the control.
- A pea gravel diaphragm and gentle side slopes shall be provided along the top of channels to provide pretreatment for lateral sheet inflows.

E. OUTLET STRUCTURES

Dry Swale

- The underdrain system shall discharge in a non-erosive manner.

Wet Swale

- Outlet protection shall be used at any discharge point from a wet swale to prevent scour and erosion.

F. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right-of-way or drainage easement shall be provided for the length of the enhanced swale from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles. The right-of-way shall be located such that maintenance vehicles and equipment can access the entire enhanced swale.

G. LANDSCAPING

- The water quality management plan shall specify the landscape design of the enhanced swale, and shall include appropriate grass species and/or wetland plants based on specific site, soil and hydric conditions present. Vegetation shall be limited to grasses and non-woody wetland plants. Trees and other large woody plant species are not appropriate for use in an enhanced swale and are prohibited.

Dry Swale

- Turf grasses that require minimal maintenance shall be used in dry swales. Native grasses are preferred, but not required. Maintenance of the turf grasses shall be performed as appropriate to maintain a stable and viable coverage of the swale bottom and side slopes.

Wet Swale

- At the time of construction, emergent vegetation shall be planted in the swale, or wetland soils may be spread on the swale bottom for seed stock. More information on wetland plants can be found at the following websites:
    - http://wetlands.fws.gov/
    - http://www.npwrc.usgs.gov/resource/plants/floraso/species.htm
- Where wet swales do not intercept the groundwater table, a water balance calculation shall be performed to ensure an adequate water budget to support the specified wetland species. See Chapter 3 for guidance on water balance calculations.

H. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

There are a number of additional site specific design criteria and issues (listed below) that must be considered in the design of an enhanced swale.

Physiographic Factors - Local terrain design constraints

- Low Relief – Reduced need for use of check dams
- High Relief – Not feasible if slopes are greater than 4%
- Karst – No exfiltration of runoff from dry swales located in hotspot land uses; an impermeable liner shall be utilized for swales that control stormwater discharges from hotspot land uses.

Special Downstream Watershed Considerations

- Wellhead Protection – Reduce potential groundwater contamination (in required wellhead protection areas) by preventing infiltration of runoff from land uses that have a high pollution potential. May require liner for type "A" and "B" soils; Pretreat runoff from polluted areas and hotspot land uses; 2 to 4 foot separation distance from water table

4.3.8.6 Design Procedures

Step 1. Compute appropriate runoff control volumes and peak discharges

Calculate WQv, CPv, and the locally regulated peak discharges, in accordance with the guidance presented in Chapter 3.

Step 2. Determine if the development site and conditions are appropriate for the use of an enhanced swale system (dry or wet swale).

Consider the subsections 4.3.8.4 and 4.3.8.5-A (Location and Siting). Check with the local jurisdiction and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 3. Determine pretreatment volume

The sediment forebay should be sized to contain 0.1 inches per impervious acre (363 ft^3) of contributing drainage. The forebay storage volume counts toward the total WQv requirement, and should be subtracted from the WQv for subsequent calculations.

Step 4. Determine swale dimensions and compute number of check dams (or similar structures) required to detain WQv as per the above stated design criteria.

Size bottom width, depth, length, and slope necessary to store WQv with less than 18 inches of ponding at the downstream end.

- Slope cannot exceed 4% (1 to 2% recommended)
- Bottom width should range from 2 to 8 feet
- Ensure that side slopes are no greater than 2:1

Step 5. Calculate draw-down time

Dry swale: Planting soil should pass a maximum rate of 1.5 feet in 24 hours and must completely filter WQv within 48 hours.

Wet swale: Must hold the WQv.

Step 6. Check for erosion potential and freeboard at the local design storm flows

Check for erosive velocities and modify design as appropriate. Provide 6 inches of freeboard for the 25-year event.

Step 7. Design low flow orifice at downstream headwalls and check dams

Design orifice to pass WQv in six hours.

Step 8. Design inlets, sediment forebay(s), and underdrain system (dry swale)

See design criteria above for further details.

Step 9. Prepare Vegetation and Landscaping Plan

A landscaping plan for a dry or wet swale shall be submitted with the stormwater management plan that indicates the vegetation proposed for the swale, and how the enhanced swale system will be stabilized and established with vegetation.

This page left intentionally blank

4.3.8.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.8.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of enhanced swales as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local jurisdiction has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for enhanced swales, along with a suggested frequency for each activity. Individual enhanced swales may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e.., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the swale in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• Inspect after seeding and after first major storm for any damage to vegetation, side slopes and bottom.	Post construction
• Inspect for signs of erosion, unhealthy or damaged vegetation, denuded areas, channelization of flow, debris and litter, and areas of sediment accumulation. Perform inspections at the beginning and end of the wet season. Additional inspections after periods of heavy rainfall are desirable.	Semi-annually
• Inspect level spreader for clogging (if applicable), grass along side slopes for erosion and formation of rills or gullies, and sand/soil bed for erosion problems. Inspect pea gravel diaphragm for clogging. • Inspect sediment forebays and/or pretreatment areas for debris and sediment accumulation.	Annually
Maintenance Activities	**Suggested Schedule**
• Mow grass to maintain a height of 3–4 inches, for safety, aesthetic, or other purposes, if needed. Litter should always be removed prior to mowing. Grass clippings, if captured, should not be dumped in the swale. • Irrigate swale during dry season (April through October) or when necessary to maintain the vegetation. • Repair damaged areas (e.g., erosion rills or gullies) and re-establish vegetation where needed. Remove invasive species manually. The use of fertilizers, herbicides and pesticides should occur only when absolutely necessary, and then in minimal amounts.	As needed (frequent, seasonally)
• Remove litter, branches, rocks blockages, and other debris and dispose of properly. • Clear accumulated debris and sediment from the inlet flow spreader (if applicable) and pea gravel diaphragm.	Semi-annually
• Inspect pea gravel diaphragm for clogging and correct the problem. • Plant an alternative grass species if the original grass cover has not been successfully established. Reseed and apply mulch to damaged areas.	Annually (if needed)
• Remove all accumulated sediment that may obstruct flow through the swale. Sediment accumulating near culverts and in channels should be removed when it builds up to 3 in. at any spot, or covers vegetation, or once it has accumulated to 10% of the original design volume. Replace the grass areas damaged in the process. • Remove all accumulated sediment in the sediment forebay and pretreatment areas. • Repair areas of erosion around swale and underdrain outlets. Reestablish soil stabilization measures (e.g., rip-rap stone, turf grasses) as needed. • Roto-till or cultivate the surface of the sand/soil bed of dry swales if the swale does not draw down within 48 hours. Re-establish swale vegetation after roto-till activities.	As needed (infrequent)

The local jurisdiction encourages the use of the inspection checklist that is presented on the next page to guide the property owner in the inspection and maintenance of enhanced swales. The local jurisdiction can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the enhanced swale.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
ENHANCED SWALE INSPECTION CHECKLIST

Location: ____ Owner Change since last inspection? Y N
Owner Name, Address, Phone: ____
Date: ___________ Time: ______________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Enhanced Swale		
Healthy vegetation?		
Erosion on bottom or side slopes?		
Animal burrows in swale?		
Clear of debris and functional?		
Check dams in place (if applicable)?		
Evidence of sediment accumulation?		
Unintentional obstructions or blockages?		
Clogged pea gravel diaphragm?		
Undesirable vegetation growth?		
Visible pollution?		
Other (describe)?		
Inlet/Outlet Channels		
Clear of debris and functional?		
Sediment accumulation?		
Signs of erosion?		
Other (describe)?		
Sediment Forebays or Pretreatment Areas		
Evidence of sediment accumulation?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature: ______________________________ **Inspector Name (printed)**________________________

4.3.8.8 Example Schematics

Figure 4-40. Schematic of a Dry Swale
(Source: Center for Watershed Protection)

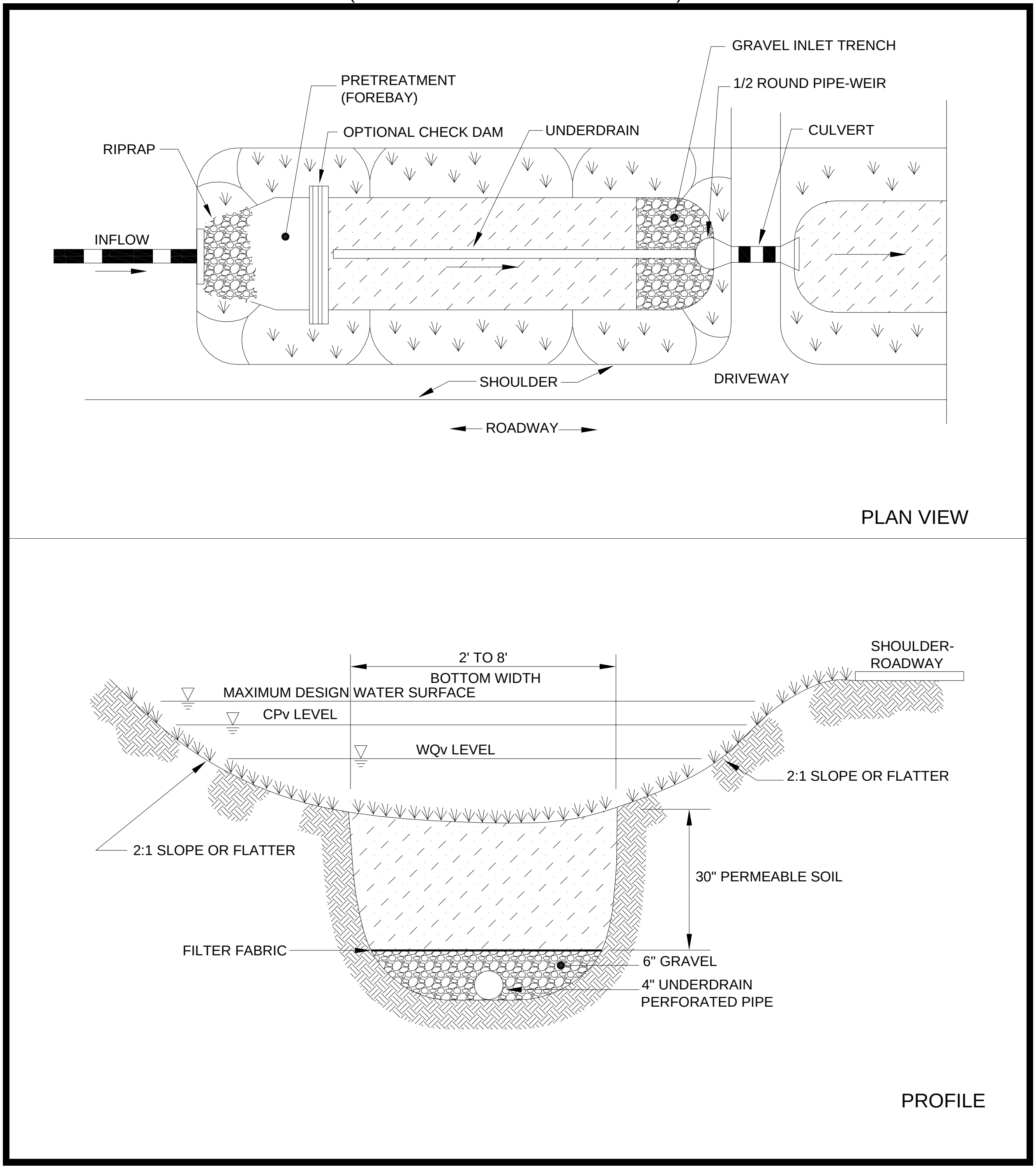
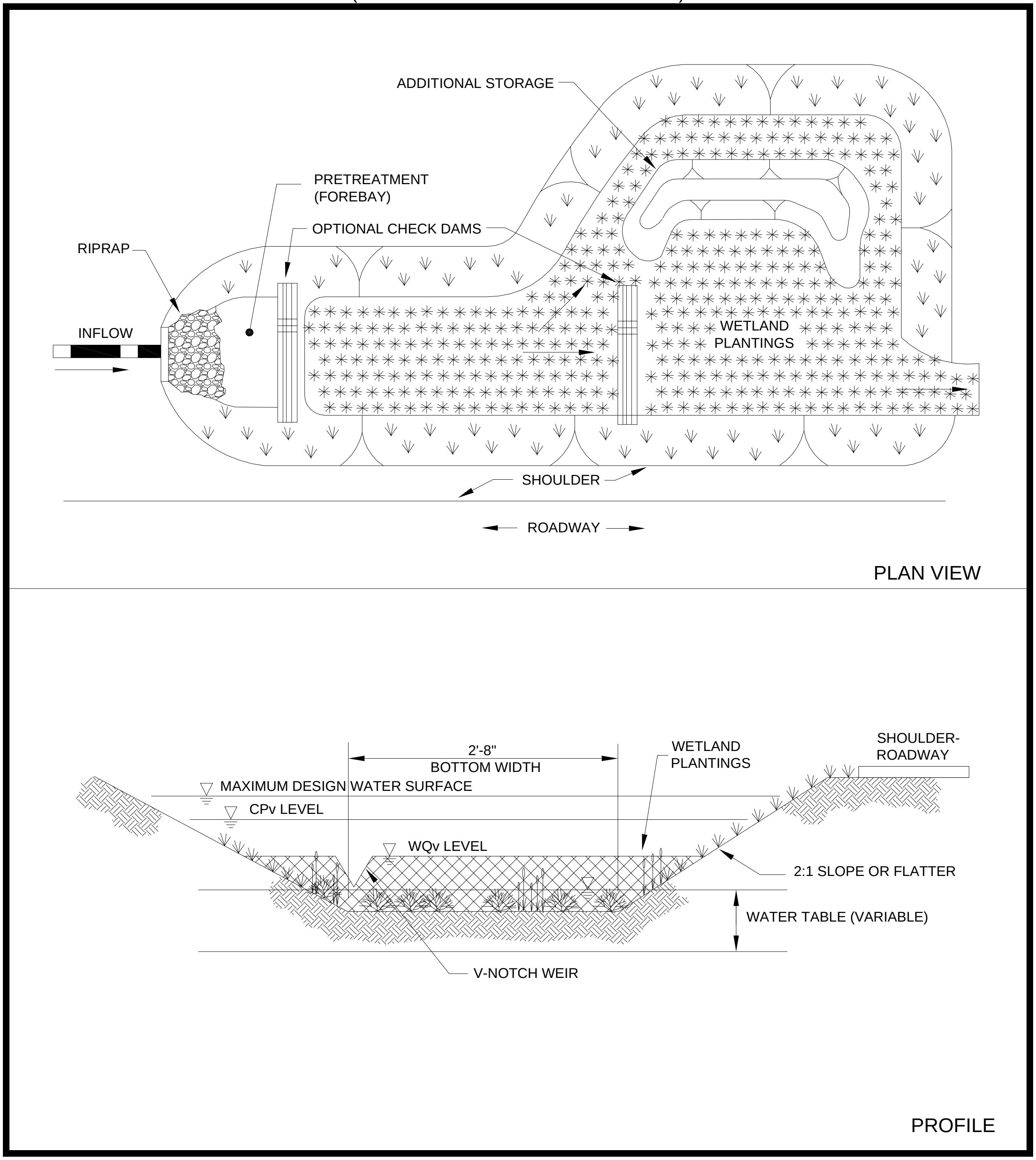


Figure 4-41. Schematic of a Wet Swale
(Source: Center for Watershed Protection)



4.3.8.9 Design Form

The local jurisdiction recommends the use of the following design procedure forms when designing enhanced swales. Proper use and completion of the form may allow a faster review of the Water quality Management Plan by the local jurisdiction.

Design Procedure Form: Enhanced Swales

PRELIMINARY HYDROLOGIC CALCULATIONS	
1a. Compute WQv volume requirements	
Compute Runoff Coefficient, Rv	Rv = ______
Compute WQv	WQv = ______ acre-ft
1b. Compute CPv	CPv = ______ acre-ft
ENHANCED SWALE DESIGN	
2. Is the use of an enhanced swale appropriate?	***See subsections 4.3.8.4 and 4.3.8.5 - A***
Confirm design criteria and applicability.	***See subsection 4.3.8.5 - J***
3. Pretreatment Volume (Forebay)	
V_{pre} =(I)(.1")(1'/12")	V_{pre} = ______ acre-ft
4. Determine swale dimensions	
Assume trapezoidal channel with max depth of 18 inches	
	Length = ______ ft
	Width = ______ ft
	Side Slopes = ______
	Area = ______ ft^2
Compute number of check dams (or similar structures) required to detain WQv	
	Slope = ______ ft/ft
	Depth = ______ ft
	Distance = ______ ft
	Number = ______ each
5. Calculate draw-down time	
Require k = 1.5 ft per day for dry swales	t = ______ hr
6. Check erosion potential and freeboard	V_{min} = ______ fps
Requires separate computer analysis for velocity	
Overflow wier (use weir equation)	Weir Length = ______ ft
Use weir equation for slot length ($Q = CLH^{3/2}$)	
7 Design low flow orifice at headwall	
Area of orifice from orifice equation	Area = ______ ft^2
$Q = CA(2gh)^{0.5}$ C varies with orifice condition	diameter ______ inches
8 Design inlets, sediment forebays, outlet structures, maintenance access, and safety features.	***See subsection 4.3.8.5 - D through H***
9. Design landscaping plan (including wetland vegetation)	

Notes: ____

4.3.8.10 References

Atlanta Regional Council (ARC). Georgia *Stormwater Management Manual Volume 2 Technical Handbook.* 2001*.*

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center, Accessed July 2005. *www.stormwatercenter.net*

City of Nashville, Tennessee. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

Connecticut Department of Environmental Protection. *Stormwater Quality Manual.* 2004.

Federal Highway Administration (FHWA), United States Department of Transportation. *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring.* Accessed January 2006. http://www.fhwa.dot.gov/environment/ultraurb/index.htm

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

Natural Resources Conservation Service (NRCS), United States Department of Agriculture, www.soils.gov

4.3.8.11 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual. Environmental and Conservation Services, 1998.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

4.3.9 Filter Strip

General Application Water Quality BMP

Description: Filter strips are uniformly graded and densely vegetated sections of land engineered and designed to treat runoff and remove pollutants through vegetative filtering and infiltration.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Drainage area size based on flow length and slope.
- Must have slopes between 2% and 6%.
- Must maintain sheet flow across the entire filter strip.
- Minimum 15 ft flow length; the longer the flow length, the higher the pollutant removal, if sheet flow is maintained.

ADVANTAGES / BENEFITS:

- High community acceptance in any type of setting.
- Easy to maintain once ground cover and/or trees are established.
- Can be used as pre-treatment for other BMPs, with an effect similar to a sediment forebay.
- Filter strips are easily incorporated into new construction/development designs.

DISADVANTAGES / LIMITATIONS:

- Cannot meet the 80% TSS goal without another BMP in a treatment train. A 50' filter strip is assumed to achieve a 50% TSS removal. A 25 ft strip is assumed to achieve a 10% TSS removal.
- Filter strips and level spreaders have limited drainage areas.
- It can be difficult to construct a level lip on level spreaders.

MAINTENANCE REQUIREMENTS:

- Maintain a dense, healthy stand of grass and other vegetation.
- Repair areas of erosion and re-vegetate as needed.
- Remove sediment build-up.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**No**
Detention/Retention:	**No**

Accepts hotspot runoff: *Yes, with pre-treatment*

COST CONSIDERATIONS

Land Requirement:	**Med - High**
Capital Cost:	**Low**
Maintenance Burden:	**Low**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids (less than 10 feet):	**0%**
Total Suspended Solids (between 10 and 50 feet):	**10%**
Total Suspended Solids (greater than 50 feet):	**50%**

4.3.9.1 General Description

Filter strips are uniformly graded and densely vegetated sections of land, engineered and designed to treat runoff and remove pollutants through vegetative filtering and infiltration. Because they cannot accept channelized runoff, filter strips are best suited to treating runoff from roads and highways, roof downspouts, very small parking lots, and pervious surfaces. They are also ideal for use as pre-treatment measures for a stream buffer or structural stormwater controls such as enhanced swales or basins. Filter strips can serve as a buffer between incompatible land uses, can be landscaped to be aesthetically pleasing, and can provide groundwater recharge in areas with pervious soils.

Pollutant removal from filter strips is highly variable and depends primarily on density of vegetation and contact time for filtration and infiltration. These, in turn, depend on soil and vegetation type, slope, and presence of sheet flow. Pollutant removal efficiencies are based upon a 50-foot long strip. Filter strips with shorter flow lengths are considered to have lower removal efficiencies and should be used as coarse sediment settling areas for other structural controls. Filter strips are often considered to be an integral component of those controls, similar to sediment forebays for stormwater basins or other structural BMPs. Uniform sheet flow must be maintained through the filter strip to provide pollutant reduction and avoid erosion. To obtain sheet flow when discharging runoff from a developed area, a level spreader may be required.

There are two different filter strip designs: a simple filter strip and a design that includes a permeable berm at the bottom. The presence of the berm increases the contact time between the filter strip and the runoff, thus reducing the overall width of the filter strip required to treat stormwater runoff. An example schematic of a filter strip is presented in Figure 4-42.

4.3.9.2 Stormwater Management Suitability

Filter strips are designed primarily for stormwater quality and do not have the ability to provide channel protection or flood protection.

<u>Water Quality (WQv)</u>
To treat stormwater runoff, filter strips rely on the use of vegetation to slow runoff velocities and filter out sediment and other pollutants from urban stormwater. There can also be a significant reduction in runoff volume for smaller flows that infiltrate through pervious soils within the filter strip. To be effective, however, sheet flow must be maintained across the entire filter strip. Once runoff flow concentrates, it effectively short-circuits the filter strip and reduces any water quality benefits. Therefore, a flow spreader must normally be included in the filter strip design.

4.3.9.3 Pollutant Removal Capabilities

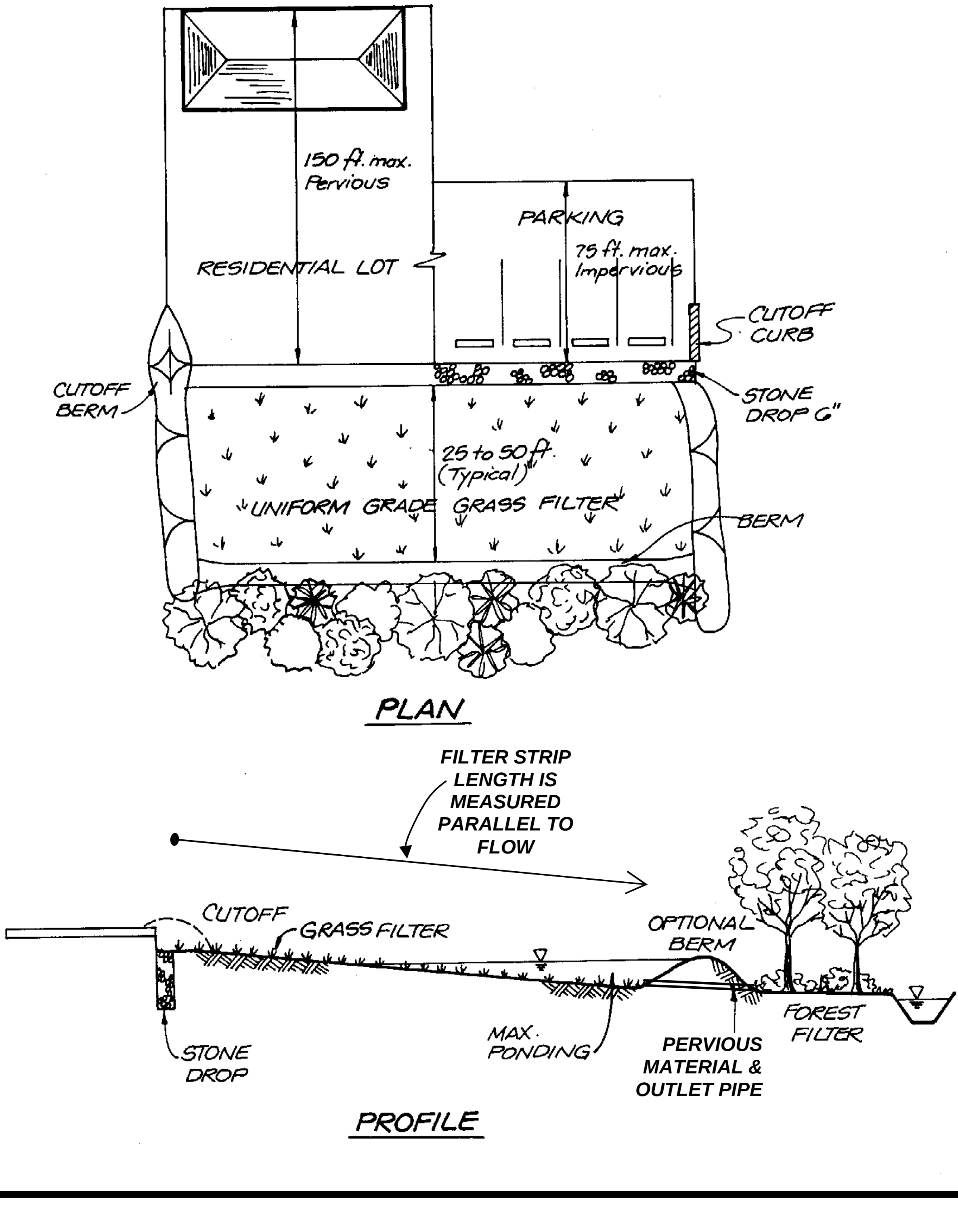
The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment. Research indicates that the pollutant removal ability of a filter strip is highly dependant upon the minimum flow path length, as follows.

<u>*Filter Strips that have a minimum flow path length of 50 feet or greater:*</u>
- Total Suspended Solids – 50%

<u>*Filter Strips that have a minimum flow path length between 25 feet and 50 feet (pretreatment control for coarse sediments):*</u>
- Total Suspended Solids – 10%

Filter strips that have a flow path length less than 25 feet are assigned a 0% TSS removal value.

Figure 4-42. Schematic of a Filter Strip (with Berm)



4.3.9.4 Application and Feasibility Criteria

Filter strips can be used in a variety of development types. However, because of their relatively large land requirement, filter strips are generally not determined to be useful in higher density areas. The topography and proposed site layout will determine the applicability of filter strips.

General Feasibility

- Suitable for use in residential subdivisions and in non-residential areas.
- Can be used in high density/ultra-urban areas, but land requirements may preclude their use.
- Not suitable for use as a regional stormwater control.

4.3.9.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of a filter strip. Filter strips that are not designed to these standards will not be approved. The local jurisdiction shall have the authority to require additional design conditions if deemed necessary.

A. LOCATION AND SITING

- Filter strips are most appropriate for treating the stormwater runoff from small drainage areas. Flow must enter the filter strip as sheet flow spread out over the length (long dimension normal to flow) of the strip. The design depth of flow shall be no greater than 2 inches. As a rule, flow starts to channelize within a maximum of 75 feet for impervious surfaces, and 150 feet for pervious surfaces (CWP, 1996). For longer flow paths, special provision must be made to ensure design flows spread evenly across the filter strip.
- A level spreader may be needed to achieve sheet flow, the design of which should be factored into the location and siting of the filter strip and into the overall site layout. Level spreader design is presented in Chapter 3 of this manual.
- Filter strips should be integrated into site designs.
- Filter strips should be constructed outside the natural stream buffer area whenever possible to maintain a more natural buffer along the streambank.
- Filter strips shall not be in areas or on soils that cannot sustain a dense vegetative cover with high retardance.
- Pedestrian traffic across the filter strip should be limited through channeling onto sidewalks.
- Each filter strip shall be placed in an easement that is recorded with the deed. The easement shall be defined at the outer edge of the filter strip.

B. PHYSICAL SPECIFICATIONS / GEOMETRY

- Filter strips shall be designed having a slope between 2% and 6%. Greater slopes than this will encourage the formation of concentrated flow. Flatter slopes will encourage standing water. Both the top and toe of the slope shall be as flat as possible to encourage sheet flow and prevent erosion.
- The filter strip shall have a minimum length (flow path) of 25 feet long to provide filtration and contact time for water quality treatment. At least fifty (50) feet is necessary to achieve the 50% TSS removal value.
- Flow must enter the filter strip as sheet flow, designed to spread out over the width of the strip with a depth of 1 to 2 inches.
- The design of the filter strip and the area draining to the filter strip shall be such that stormwater flows in excess of the design flow can discharge across or around the strip without causing erosion or other damage. Often a bypass channel or overflow spillway with a protected channel section is designed to handle higher flows.

- An effective flow spreader is to use a pea gravel diaphragm at the top of the slope (ASTM D 448 size no. 6, 1/8" to 3/8"). The pea gravel diaphragm (a small trench running along the top of the filter strip) serves two purposes. First, it acts as a pre-treatment device, settling out sediment particles before they reach the practice. Second, it acts as a level spreader, maintaining sheet flow as runoff flows over the filter strip. Other types of flow spreaders include a concrete sill, curb stops, or curb and gutter with "sawteeth" cut into it. Level spreader design can be found in Chapter 3 of this manual.

- Maximum discharge loading per foot of filter strip width (perpendicular to flow path) shall be determined using the Manning equation:

Equation 4.3.9.1

$$q = \frac{0.00236}{n} Y^{\frac{5}{3}} S^{\frac{1}{2}}$$

where: q = discharge per foot of width of filter strip (cfs/ft)
Y = allowable depth of flow (inches) = 2 inches maximum
S = slope of filter strip (percent)
n = Manning's "n" roughness coefficient (use 0.15 for medium grass, 0.25 for dense grass, and 0.35 for very dense Bermuda-type grass)

- Using *q* computed above, the minimum width of a filter strip shall be calculated using the following equation:

Equation 4.3.9.2

$$W_{fMIN} = \frac{Q_{wq}}{q}$$

where: W_{fMIN} = minimum filter strip width perpendicular to flow (feet)
Q = peak discharge of stormwater runoff (cfs)
q = discharge per foot of width of filter strip (cfs/ft)

Filter Strips without a permeable berm:

- The length of the filter strip (parallel to flow path across the filter strip) shall be sized to achieve a contact time between the stormwater runoff and filter strip vegetation of no less than five (5) minutes. The equation for filter strip length (the flow path) is based on the SCS TR-55 travel time equation (SCS, 1986):

Equation 4.3.9.3

$$L_f = \frac{(T_t)^{1.25}(P_{2-24})^{0.625}(S)^{0.5}}{3.34n}$$

where: L_f = length of filter strip parallel to flow path (ft)
T_t = travel time through filter strip (minutes), minimum 5 minutes
P_{2-24} = 2-year, 24-hour rainfall depth (inches)
S = slope of filter strip (percent)
n = Manning's "n" roughness coefficient (use 0.15 for medium grass, 0.25 for dense grass, and 0.35 for very dense Bermuda-type grass)

Filter Strips with a permeable berm:

- The filter strip shall be sized to contain the entire WQv within the wedge of water that backs up behind the berm.

- The maximum height of the berm is 12 inches.

- Outlet pipes from the berm shall be sized to ensure that the runoff stored behind the berm drains within 24 hours.

- The outlet pipes shall be designed such that runoff discharges from the berm in a non-erosive manner.

- The berm shall be constructed of a mixture of sand, gravel and sandy loam to encourage grass cover. Specifications for sand and gravel are: sand - ASTM C-33 fine aggregate concrete sand 0.02”-0.04”; gravel - AASHTO M-43 ½” to 1”.

Filter Strips used for pre-treatment:

- A number of other structural controls, including bioretention areas and infiltration trenches, may utilize a filter strip as a pre-treatment measure. The required length of the filter strip depends on the drainage area, imperviousness, and the filter strip slope. Table 4-9 provides sizing guidance for using filter strips for pre-treatment.

Table 4-9. Sizing of Filter Strips for Pre-treatment

(Source: Adapted from Georgia Stormwater Management Manual)

Parameter	Impervious Areas[1]				Pervious Areas (Lawns, etc)[2]			
Maximum inflow approach length (feet)	35		75		75		100	
Filter strip slope (max = 6%)	≤ 2%	> 2%	≤ 2%	> 2%	≤ 2%	> 2%	≤ 2%	> 2%
Filter strip minimum length (feet)[3]	10	15	20	25	10	12	15	18

1 – 75 feet maximum impervious area flow length to filter strip.
2 – 150 feet maximum pervious area flow length to filter strip.
3 – At least 25 feet is required for minimum pre-treatment credit of 10% TSS removal. Fifty feet is required for 50% removal.

C. SPECIAL CONSIDERATIONS FOR THE AS-BUILT CERTIFICATION

- Like any other water quality BMP, the filter strip must be shown on the as-built certification specifically as a water quality BMP. The following components must be addressed in the as-built certification:

  1. Ensure the design flows are spread evenly across the filter strip.
  2. Ensure the design slope is between 2% and 6%.
  3. The dimensions of the filter strip must be verified.
  4. The type of vegetation used in the filter strip.

D. MAINTENANCE ACCESS

- A minimum 20 foot wide maintenance right-of-way or drainage easement shall be provided for the length and width of the filter strip from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles. The right-of-way shall be located such that maintenance vehicles and equipment can access the entire filter strip.

E. LANDSCAPING

- The vegetation in a filter strip can be grassed, or a combination of grass and woody plants. Filter strips that are vegetated with forest vegetation may be able to qualify as a water quality volume (WQv) reduction. See Chapter 5 for more information on the stream and vegetated buffer reduction.

- Designers should choose a grass that can withstand relatively high velocity flows at the entrances, and both wet and dry periods.

- For filter strips with a permeable berm, vegetation that can withstand frequent inundation must be utilized in the area where shallow ponding will occur.

4.3.9.6 Design Example

Basic Data

Small commercial lot 150 feet deep x 100 feet wide

- Drainage area (A) = 0.34 acres
- Impervious percentage (I) = 70%
- Slope equals 4%
- Manning's n = 0.25

Step 1: Calculate Maximum Discharge Loading Per Foot of Filter Strip Width (q):

Using Equation 4.3.9.1 above:

$q = (0.00236/0.25) * (1.0)^{5/3} * (4)^{1/2} = 0.019$ cfs/ft

Step 2: Calculate the Water Quality Flow Rate (Q_{wq}):

(See Chapter 3 for equation information)
Compute the Runoff Peak Volume (Q_{wv}) in inches for 1.1-inch rainfall (P = 1.1):

$Q_{wv} = PRv = 1.1Rv = 1.1(0.015 + (0.0092)(70)) = 0.72$ inches

Compute modified CN:

$$CN = 1000/[10+5P+10\,Q_{wv} - 10(Q_{wv}^{\ 2}+1.25Q_{wv}P)^{½}]$$
$$= 1000/[10+5(1.1)+10(0.72)-10(0.72^2+1.25(0.72)1.1)^{½}]$$
$$= 95.98 \text{ (Use CN = 96)}$$

For CN = 96 and an estimated time of concentration (T_c) of 8 minutes (0.13 hours), compute the Q_{wq} for a 1.1 inch storm.

$I_a = 0.083$ (from Table 3-14 in Chapter 3), therefore $I_a/P = 0.083/1.1 = 0.075$.

Using Figure 3-6 in Chapter 3, q_u can be estimated for a Type II storm at approximately 950 csm/in.
q_u = 950 csm/in, and therefore:

$Q_{wq} = q_u A\, Q_{wv}$ = (950 csm/in) (0.34ac/640ac/mi^2) (0.72in) = 0.36 cfs

Step 3: Calculate the Minimum Filter Width

Using Equation 4.3.9.2 above:

$W_{fMIN} = Q_{wq}/q = 0.36/0.019 = 19$ feet

Since the width of the lot is 100 feet, the actual width of the filter strip will depend on site grading and the ability to deliver the drainage to the filter strip in sheet flow through a pea gravel filled trench.

The next step is to calculate the filter length. This calculation is different for a filter designed without a permeable berm (presented in Step 4a), than for a filter designed with a berm (presented in Step 4b).

Step 4a: Calculate the Filter Length (L_f) for a filter without a berm:

Basic Data:

- Depth of 2-year, 24-hour storm = 3.3 inches (see Chapter 3, Table 3-5)
- Use 5 minute travel (contact) time

Using Equation 4.3.9.3 above:

$L_f = (5)^{1.25}(3.3)^{0.625}(4)^{0.5} / (3.34)(0.25) = 37.8$ feet (use 38 feet)

Note: Reducing the filter strip slope to 2% and planting a more dense grass (raising the Manning "n" to 0.35) would reduce the filter strip length to 19 feet.

Step 4b: Calculate the Filter Length (assume filter is designed with a berm):

(See Chapter 3 for equation information)

Basic Data:

- The height of the permeable berm (h) will be 6 inches (0.5 feet).
- Assume the filter width = the maximum lot width (W_f) = 100 feet.

Compute the Water Quality Volume (WQv) in cubic feet:

$WQv = 1.1R_vA/12 = 1.1(0.015 + 0.0092(70))0.34/12 = 0.021$ ac-ft or 895 ft^3

This is the volume of the "wedge" of water that ponds behind the berm.

For a berm height of 6 inches (0.5 feet), the "wedge" of volume captured by the filter strip is:

The area of the "wedge" = $½L_fh$, therefore,

The volume of the "wedge" = $W_f½L_fh$ =(100) ½(L_f)(0.5) = 895 ft^3

Solving for L_f, the length of the filter = 35.8 feet (use 36 feet).

Note: Increasing the berm height to 1 foot will result in a filter length of 18 feet.

4.3.9.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.9.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective use of filter strips as stormwater best management practices. It is the responsibility of the property owner to maintain all stormwater facilities in accordance with the minimum design standards and other guidance provided in this manual. The local jurisdiction has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for filter strips, along with a suggested frequency for each activity. Individual filter strips may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain filter strips properly at all times.

Inspection Activities	Suggested Schedule
• Inspect pea gravel diaphragm for clogging (i.e., standing water or sediment build-up). • Inspect vegetation for signs of erosion or un-vegetated areas. • Inspect to ensure that grass has established. • Inspect general flow paths to determine if runoff discharges into and across the filter strip in an unchannelized fashion.	Annually (Semi-annually first year)
Maintenance Activities	**Suggested Schedule**
• Maintain a dense, healthy stand of grass and other vegetation by frequent mowing. Grass heights of 3 to 5 inches should be maintained, with a maximum grass height of 8 inches.	Regularly (frequently)
• Repair areas of erosion and re-vegetate. • Re-vegetate as needed to maintain healthy vegetation. • Remove sediment buildup.	As needed

The local jurisdiction encourages the use of the inspection checklist presented below for guidance in the inspection and maintenance of the filter strip. The local jurisdiction can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the filter strip. Questions regarding inspection and maintenance should be referred to the local jurisdiction.

INSPECTION CHECKLIST FOR FILTER STRIPS

Location: ____ Owner Change since last inspection? Y N
Owner Name, Address, Phone: ____
Date: ___________ Time: ______________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Healthy vegetation?		
Signs of erosion?		
Clogged pea gravel diaphragm?		
Sediment buildup behind level spreader at top?		
Sediment buildup in filter strip?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:________________________________ Inspector Name (printed)____________________________

4.3.9.8 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

City of Nashville, Tennessee. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

4.3.9.9 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management*. Environmental Criteria Manual. Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

Driscoll, E., and P. Mangarella. *Urban Targeting and BMP Selection.* Prepared by Woodward-Clyde Consultants, Oakland, CA, for U.S. Environmental Protection Agency, Washington, DC, 1990.

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

Metropolitan Washington Council of Governments (MWCOG), *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March 1992.

Urbonas, B.R., J.T. Doerfer, J. Sorenson, J.T. Wulliman, and T. Fairley. *Urban Storm Drainage Criteria Manual. Vol. 3. Best Management Practices, Stormwater Quality.* Urban Drainage and Flood Control District, Denver, CO, 1992.

Wong, S.L., and R.H. McCuen. *The Design of Vegetative Buffer Strips for Runoff and Sediment Control. Appendix J in Stormwater Management for Coastal Areas.* American Society of Civil Engineers, New York, New York, 1982.

This page left intentionally blank

4.3.10 Grass Channel

General Application Water Quality BMP

Description: Grass channels are vegetated open channels that are designed to filter stormwater runoff, as well as slow water for treatment by another structural BMP.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Broad bottom channel on slopes of 4% or less.
- Gentle side slopes (3:1 (H:V) or less).
- Check dams can be installed to maximize treatment.
- Requires vegetation that can withstand both relatively high velocity flows and wet and dry periods.
- Maximum contributing drainage area of 5 acres.

ADVANTAGES / BENEFITS:

- Provides pretreatment if used as part of runoff conveyance system.
- Provides partial infiltration of runoff in suitable soil conditions.
- Generally less expensive than extruded curb.
- Good for small drainage areas.
- Relatively low maintenance requirements.
- Well suited to a large number of applications.

DISADVANTAGES / LIMITATIONS:

- Cannot alone achieve 80% removal of TSS.
- Must be carefully designed to achieve low flow rates in the channel for WQv purposes (<1.0 ft/s).
- May re-suspend sediment.
- May not be acceptable for some areas because of standing water in channel.

MAINTENANCE REQUIREMENTS:

- Maintain a dense, healthy stand of grass.
- Repair areas of erosion and re-vegetate as needed.
- Remove sediment buildup.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**No**
Detention/Retention:	**No**

Accepts hotspot runoff: *Yes, with pre-treatment*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**Low**
Maintenance Burden:	**Low**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	✷
Commercial/Industrial Use:	✷

✷ in certain situations

POLLUTANT REMOVAL

Total Suspended Solids:	**30%**

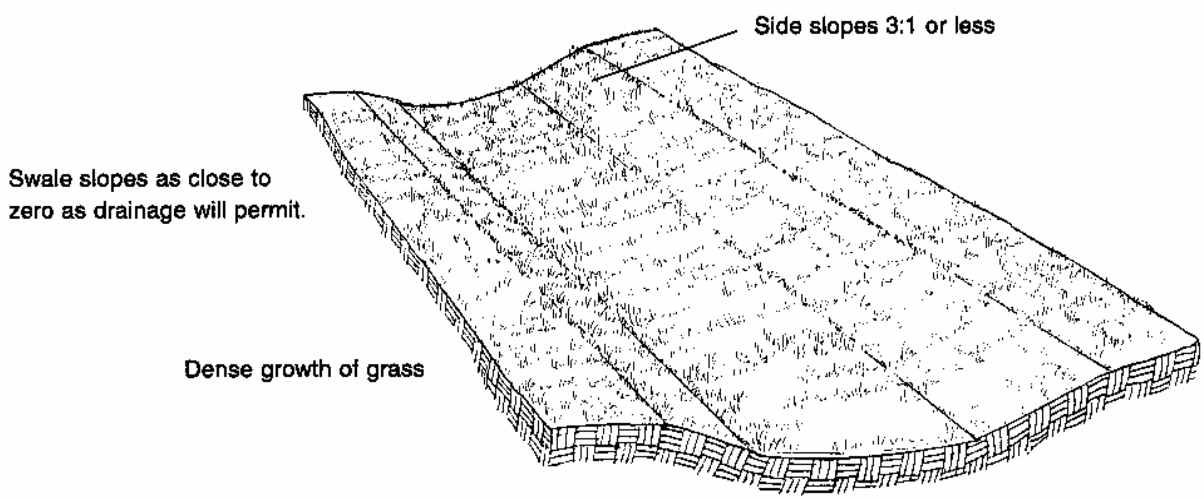
4.3.10.1 General Description

Grass channels, sometimes called biofilters, are conveyance channels that are designed to provide some treatment of runoff, as well as to slow down runoff velocities for treatment in other structural controls. Grass channels are appropriate for a number of applications including treating runoff from paved roads and from pervious areas.

In addition to their ability to provide a minimal level of filtration of pollutants, grass channels can partially infiltrate runoff from small storm events when they are located in areas that have suitable soils (types A, B, and sometimes C). When properly incorporated into a site's layout, grass channels can provide other ancillary benefits, such as reduction of impervious cover, accent of natural features and reduced construction and maintenance costs when compared with traditional extruded curb.

When designing a grass channel, the two primary considerations are channel capacity and minimization of erosion. The channel must be designed with a runoff velocity less than 1.0 foot per second during the peak discharge associated with the water quality design rainfall event, and the total length of a grass channel should provide at least 5 minutes of residence time. To enhance water quality treatment, grass channels must have broader bottoms, lower slopes and denser vegetation than most drainage channels. Additional treatment can be provided by placing check-dams across the channel below pipe inflows, and at various other points along the channel. Example schematics of grass channels are presented in Figures 4-43 and 4-44.

Figure 4-43. Typical Grass Channel



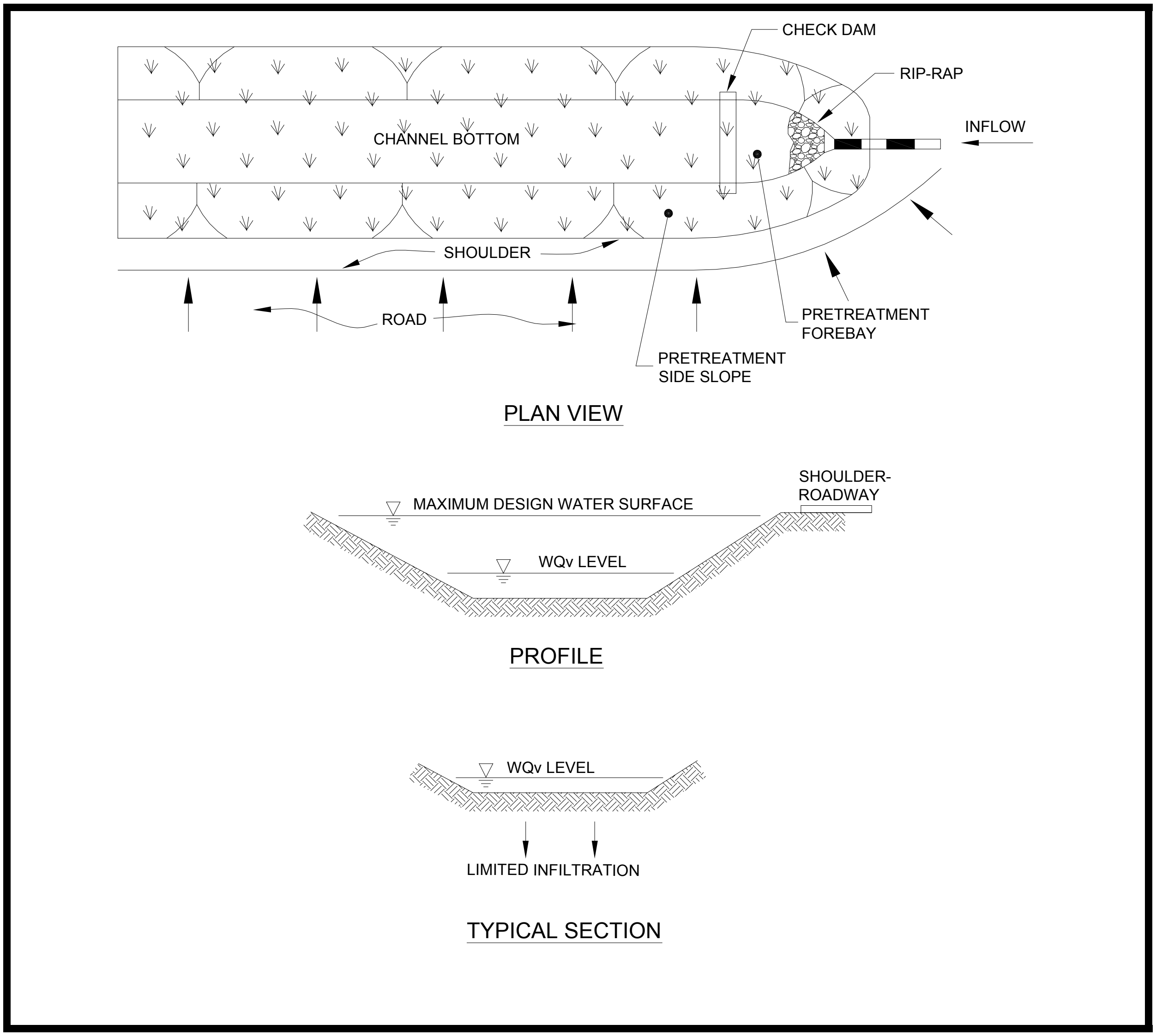
Source: Modified from Galli, 1992

4.3.10.2 Stormwater Management Suitability

Grass channels are designed primarily for stormwater quality treatment and runoff conveyance and do not have the ability to provide channel protection or flood protection.

<u>Water Quality (WQv)</u>
To treat stormwater runoff, grass channels rely on the use of vegetation to slow runoff velocities and filter out sediment and other pollutants from urban stormwater. There can also be a reduction in runoff volume for smaller flows that infiltrate through pervious soils within the filter strip.

Figure 4-44. Typical Grass Channel (Plan and Profile Views)



4.3.10.3 Pollutant Removal Capabilities

Grass channels differ from enhanced swales (discussed in Section 4.3.8 of this manual) in that they do not have an engineered filter media to enhance pollutant removal capabilities. Because of this, grass channels have a lower pollutant removal rate than for a dry or wet (enhanced) swale.

The following design pollutant removal rate is based upon a grass channel that has sufficient length for a runoff residence time (in the channel) of at least 5 minutes. The total suspended solids design pollutant removal rate of 30% is a conservative average pollutant reduction percentage for design purposes derived from sampling data, modeling and professional judgment.

4.3.10.4 Application and Feasibility Criteria

Grass channels can be used in a variety of development types. However, because of strict requirements for low slopes, grass channels will generally not be useful in developments that have steep topography.

General Feasibility

- Suitable for use in residential subdivisions and in non-residential areas.
- Can be used in high density/ultra-urban areas, but runoff velocity restrictions may preclude their use.
- Not suitable for use as a regional stormwater control due to small drainage area requirements.

4.3.10.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of a grass channel. Grass channels that are not designed to these standards will not be approved. The local jurisdiction shall have the authority to require additional design conditions if deemed necessary.

A. LOCATION AND SITING

- The drainage area (contributing or effective) for a grass channel shall be 5 acres or less. Runoff flows and volumes from larger drainage areas prevent proper filtration and infiltration of stormwater.
- Grass channels can be used on most soils. However, grass channels shall not be used for water quality treatment purposes on soils with infiltration rates less than 0.27 inches per hour.
- Each grass channel shall be placed in an easement that is recorded with the deed. The easement shall be defined from the centerline of the grass channel to the same width as that specified for stormwater pipes in the local regulations.

B. PHYSICAL SPECIFICATIONS / GEOMETRY

The following specifications apply to grass channels that are designed to achieve a % TSS removal rate of 30%. The reader should refer to, Chapter 3 for additional specifications and design information on runoff conveyance in open grass channels.

- Grass channels shall be designed on slopes of < 4%; slopes between 1% and 2% are recommended.
- A grass channel shall be designed to accommodate the peak flow for the water quality design storm, Q_{wq}, and the 2-year, 24-hour design storm without eroding (see Chapter 3 for more information on Q_{wq}). Larger flows should be accommodated by the channel if dictated by the surrounding conditions. Consult the local jurisdiction to verify if accommodation of larger flows is required.
- Grass channels shall have a trapezoidal or parabolic cross-section and shall have side slopes of 3:1 (horizontal:vertical) or flatter.
- For trapezoidal sections, the minimum width of the channel bottom shall be no less than 2 feet. The maximum width of the channel bottom shall be no greater than 6 feet. The minimum width ensures a minimum filtering surface for water quality treatment, and the maximum width prevents braiding, which is the formation of small channels within the swale bottom. The bottom width is a dependent variable in the calculation of velocity based on Manning's equation. If a larger channel is needed, the use of a compound cross section is recommended.
- The channel shall be designed to have a depth of flow no greater than 4-inches, for the WQv design flow.
- Runoff velocities carried in the channel must be non-erosive. The design velocity is for full-flow.
- The channel shall be designed such that the water quality peak flow (Q_{wq}) is contained in the channel for no less than 5-minutes. This residence time may be increased by reducing the slope, increasing the wetted perimeter, or planting a denser grass. Check dams can be utilized in the channel to maximize Q_{wq} retention time. However, the channel must not be designed to hold a permanent pool of standing water. Channel slope shall be sufficient to drain the channel if infiltration does not occur.
- The depth from the bottom of the channel to groundwater shall be at least 2 feet to prevent a moist swale bottom, or contamination of the groundwater.
- Designers should choose a grass that can withstand relatively high velocity flows at the entrances, and both wet and dry periods.

Grass Channels Used for Pretreatment:

- A number of other structural controls, including bioretention areas and infiltration trenches, may utilize a grass channel as a pretreatment measure. The length of the grass channel depends on the drainage area, land use, and channel slope. To be used as a pretreatment measure, the grass channel must have a minimum length of 20 feet. Table 4-10 provides minimum lengths for grass channels based on channel slope and percent imperviousness (of the contributing drainage area).

Table 4-10. Grass Channel Sizing Guidance
(Source: Georgia Stormwater Management Manual)

Parameter	≤ 33% Impervious		Between 34% and 66% Impervious		≥ 67% Impervious	
Slope (max = 4%)	≤ 2%	> 2%	≤ 2%	> 2%	≤ 2%	> 2%
Grass channel min. length (feet) assumes 2-ft bottom width	25	40	30	45	35	50

C. SPECIAL CONSIDERATIONS FOR THE AS-BUILT CERTIFICATION

- Like any other water quality BMP, the grass channel must be shown on the as-built certification specifically as a water quality BMP. The following components must be addressed in the as-built certification:
  1. The channel must be adequately vegetated.
  2. The channel flow velocities must not exceed 1.0 foot per second for the WQv design flow.
  3. A mechanism for overflow of large storm events must be provided.

D. MAINTENANCE ACCESS

- A minimum 20 foot wide maintenance right-of-way or drainage easement shall be provided for the length and width of the grass channel from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles. The right-of-way shall be located such that maintenance vehicles and equipment can access the entire channel.

E. LANDSCAPING

- The vegetation in a grass channel shall be composed entirely of grasses that can withstand relatively high velocity flows at the entrances and periods of inundation and drought.

4.3.10.6 Design Example

Basic Data

Small commercial lot 300 feet deep x 145 feet wide

- Drainage area (A) = 1.0 acres
- Impervious percentage (I) = 70%
- Site slope (S) = 2%

Step 1: Calculate the Water Quality Peak Flow Rate (Q_{wq}):

(See Chapter 3 for equation information)
Compute the Runoff Peak Volume (Q_{wv}) in inches for 1.1-inch rainfall (P = 1.1):

$$Q_{wv} = PRv = 1.1Rv = 1.1(0.015 + (0.0092)(70)) = 0.72 \text{ inches}$$

Compute modified CN:

$CN = 1000/[10+5P+10\ Q_{wv} - 10(Q_{wv}{}^2 + 1.25 Q_{wv} P)^{½}]$
$= 1000/[10+5(1.1)+10(0.72)-10(0.72^2+1.25(0.72)1.1)^{½}]$
$= 95.98$ (Use CN = 96)

For CN = 96 and an estimated time of concentration (T_c) of 8 minutes (0.13 hours), compute the Q_{wq} for a 1.1 inch storm.

$I_a = 0.083$ (from Table 3-14 in Chapter 3), therefore $I_a/P = 0.083/1.1 = 0.075$.

Using Figure 3-6 in Chapter 3, q_u can be estimated for a Type II storm at approximately 950 csm/in.
$q_u = 950$ csm/in, and therefore:
$Q_{wq} = q_u A\ Q_{wv}$ = (950 csm/in) (1.0ac/640ac/mi^2) (0.72in) = 1.07 cfs

Step 2: Utilize Q_{wq} to Calculate the Minimum Channel Bottom Width

The maximum flow depth for water quality treatment should be approximately the same height of the grass. A maximum flow depth of 4 inches is allowed for water quality design. A maximum flow velocity of 1.0 foot per second for water quality treatment is required. For Manning's "n" use 0.15 for medium grass, 0.25 for dense grass, and 0.35 for very dense Bermuda-type grass.

Input variables: n = 0.15
S = 0.02 ft/ft
D = 4/12 = 0.33 ft

Then: $Q_{wq} = Q = VA = 1.49/n\ D^{2/3}\ S^{1/2}\ DW$
where: Q = peak flow (cfs)
V = velocity (ft/sec)
A = flow area (ft^2) = WD
W = channel bottom width (ft)
D = flow depth (ft) *(approximates the hydraulic radius for shallow flows)*
S = slope (ft/ft)

The above equation can be solved for the minimum channel bottom width (W), as follows:
$(nQ)/(1.49\ D^{5/3}\ S^{1/2}) = W = (0.15*1.07)/(1.49*0.33^{5/3}*0.02^{1/2}) = 4.8$ feet *(minimum width)*

The velocity of the water quality peak flow rate must be less than 1.0 feet per second (fps). Check this, as follows:

V = Q/(WD) *(where WD approximates the flow area, A, for shallow flows)*
V = 1.07/(4.0 * 4/12) = 0.80 fps *(Design confirmed: the velocity is < 1.0 fps.)*

Step 3: Calculate the Channel Length

The minimum length for a 5-minute (300 seconds) residence time is calculated as follows:

V = L/T
where:
V = velocity (ft/sec)
L = channel length (ft)
T = residence time (seconds)

The above equation can be solved for the minimum channel length (L), as follows:
L = (0.8)(5*60) = 240 feet

Depending on the site geometry, the width or the slope or density of grass (Manning's "n" value) can be adjusted to slow the velocity and shorten the channel within the design specifications discussed above.

4.3.10.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.10.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective use of grass channels as stormwater best management practices. It is the responsibility of the property owner to maintain all stormwater facilities in accordance with the minimum design standards and other guidance provided in this manual. The local jurisdiction has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for grass channels, along with a suggested frequency for each activity. Individual grass channels may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain grass channels properly at all times.

Inspection Activities	Suggested Schedule
• Inspect check dams (if used) for clogging (i.e., standing water or sediment build-up). • Inspect vegetation for signs of erosion or un-vegetated areas. • Inspect to ensure that grass is healthy and well-established.	Annually (Semi-annually first year)
Maintenance Activities	**Suggested Schedule**
• Maintain a dense, healthy stand of grass and other vegetation by frequent mowing. Grass heights of 3 to 5 inches should be maintained, with a maximum grass height of 8 inches.	Regularly (frequently)
• Remove trash, debris and sediment accumulated in the channel or behind check dams (if present). • Repair areas of erosion and re-vegetate. • Re-vegetate as need to maintain healthy vegetation.	As-needed

The local jurisdiction encourages the use of the inspection checklist presented below for guidance in the inspection and maintenance of the grass channel. The local jurisdiction can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the channel. Questions regarding inspection and maintenance should be referred to the local jurisdiction.

INSPECTION CHECKLIST FOR GRASS CHANNELS

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: __________ Time: ____________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Healthy vegetation?		
Signs of erosion?		
Clogged check dams?		
Sediment build-up on channel bottom?		
Standing water for extended periods?		
Soggy channel bottom for extended periods?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:____________________________ Inspector Name (printed)________________________

4.3.10.8 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

City of Nashville, Tennessee. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

4.3.10.9 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management*. Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Horner, R.R. *Biofiltration Systems for Storm Runoff Water Quality Control.* Washington State Department of Ecology, 1988.

IEP. *Vegetated Buffer Strip Designation Method Guidance Manual.* Narragansett Bay Project, 1991.

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

This page left intentionally blank

4.3.11 Modular Porous Paver Systems

General Application Water Quality BMP

Description: A pavement surface composed of structural units with void areas that are filled with pervious materials such as sand or grass turf. Porous pavers are installed over a gravel base course that provides storage as runoff infiltrates through the porous paver system into underlying permeable soils.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Design considerations are similar to any paved area (soil properties, load-bearing design, hydrologic design of pavement and subgrade).
- Soil infiltration rate of 0.5 in/hr or greater is required, if no underdrain is present.
- The infiltration rate of native soil determines appropriateness and need for an underdrain. Soil groups “D” and “C” typically require and underdrain.
- Not appropriate for heavy or high traffic areas.

ADVANTAGES / BENEFITS:

- Reduces runoff volume, attenuates peak runoff rate and outflow.
- Can be used as pretreatment for other BMPs for pollutants other than TSS.
- High level of pollutant removal for pollutants other than TSS.

DISADVANTAGES / LIMITATIONS:

- Sediment-laden runoff can clog modular porous paver systems causing failure.
- Subgrade cannot be overly compacted.
- Construction must be sequenced to avoid compaction and clogging pavement.

MAINTENANCE REQUIREMENTS:

- Vacuum to increase porous paver system life and avoid clogging.
- Ensure that contributing area is clear of debris and areas of erosion.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**No**
Detention/Retention:	**No**

Accepts hotspot runoff: *Yes, but does not provide stormwater treatment.*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**Med-High**
Maintenance Burden:	**Med**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	✷
Commercial/Industrial Use:	✷

✷ in certain situations

POLLUTANT REMOVAL

Total Suspended Solids:	**0%**

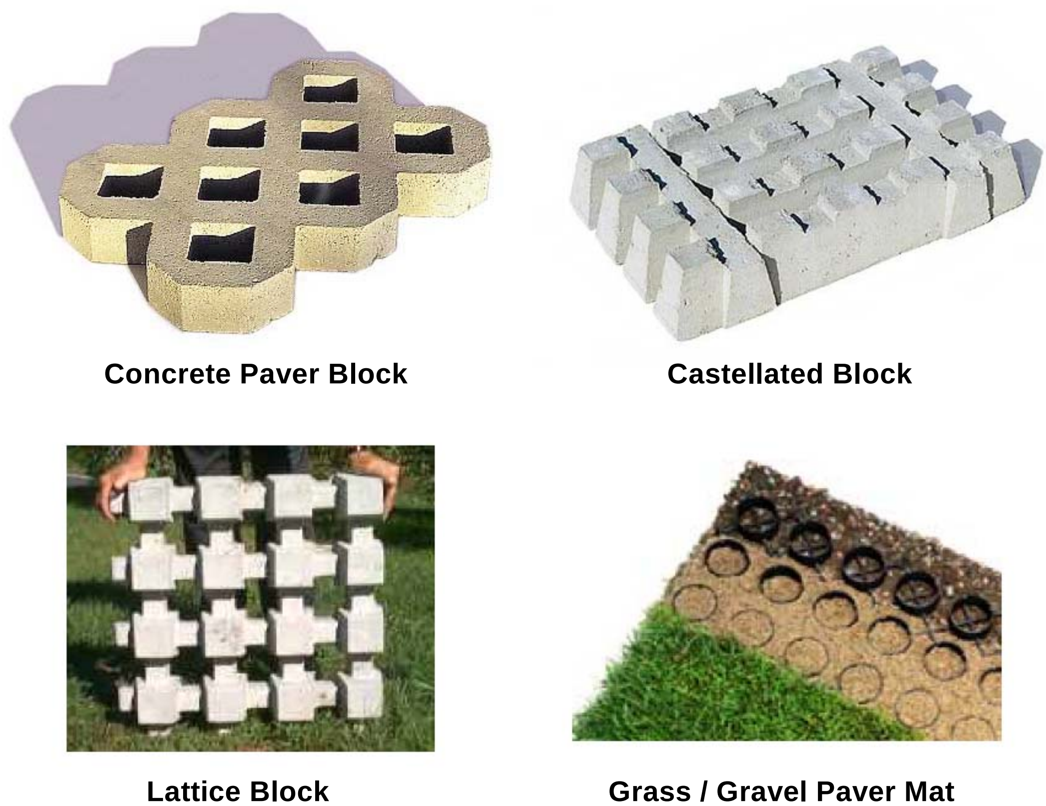
(Porous paver systems are not considered water quality removal BMPs, but are used to reduce impervious area and therefore reduces the volume required for treatment.)

4.3.11.1 General Description

While porous paver systems are not a recommended practice to reduce TSS, they are an excellent application to reduce the effective impervious area on a site, therefore, reducing the Water Quality Volume (WQv) that must be treated. Modular porous pavers are structural units, such as concrete blocks, bricks, or reinforced plastic mats, with regularly dispersed void areas used to create a load-bearing pavement surface. The void areas are filled with pervious materials (gravel, sand, or grass turf) to create a system that allows for the infiltration of stormwater runoff. Porous paver systems provide water quality benefits in addition to groundwater recharge and a reduction in stormwater volume.

There are many different types of modular porous pavers that are available from different manufacturers, including both pre-cast and mold in-place concrete blocks, concrete grids, interlocking bricks, and plastic mats with hollow rings or hexagonal cells (see Figure 4-45). The two main types of modular porous pavement systems are plastic grid and open cell paving grid.

Figure 4-45. Examples of Modular Porous Pavers



Plastic grid systems are often referred to as *geocells* and are defined by manufactured plastic lattices or mattresses that form networks of box-like cells that are filled with earth material. The lattice is typically 3 to 8 inches thick, and the cells range from 8.8 to 20 inches wide. Porosity and permeability of these systems is entirely dependent on the type of fill and vegetation that exists within each cell. Like any other pavement surface, geocells require a firm gravel base that provides strength and storage capacity as runoff infiltrates. Geocells are lightweight and easy to transport and install. However, they may be jarred easily by moving traffic, resulting in cell failure, cell movement, and possibly the need for replacement.

Open cell paving grids, commonly called *block pavers or grid pavers*, are structural units, such as concrete blocks or bricks with regularly spaced voids that penetrate their entire thickness. Grids are made of concrete or brick and the open cells are filled with porous aggregate or vegetated soil. Block pavers are more rigid and, therefore, can bear larger traffic loads than plastic grid systems.

Modular porous pavement systems are typically placed on a gravel (stone aggregate) base course. Runoff infiltrates through the porous paver surface into the gravel base course, which acts as a storage reservoir as it infiltrates to the underlying soil. The infiltration rate of the soils in the subgrade must be adequate to support drawdown of the entire runoff capture volume within 24 to 48 hours. If the surrounding soil infiltration is insufficient or if the potential for contamination of groundwater exists from pollutants such as chemicals, fertilizers, petroleum products, fats or greases, an underdrain is required to allow discharge of the runoff to additional BMPs for treatment. Additionally, special care must be taken during construction to avoid undue compaction of the underlying soils, which could affect the soils' infiltration capability.

Construction and maintenance costs and requirements should be considered when utilizing porous paver systems. Modular porous paver systems require a high level of construction workmanship to ensure that they function as designed. In addition, the repair or replacement of the surfaces can be costly should they become clogged.

4.3.11.2 Stormwater Management Suitability

Porous paver systems can not be used for stormwater treatment (i.e., 80% TSS removal) or flood control. The major benefit in using these systems lies in the overall reduction of stormwater runoff that can be provided. Areas covered by porous paver systems can be considered as pervious surfaces, thereby reducing water quality treatment and channel protection volumes, and flood protection peak discharges.

<u>Water Quality (WQv)</u>
Porous paver systems do not have the ability to provide stormwater quality treatment for total suspended solids (TSS). However, these systems provide for infiltration of stormwater and can provide for the removal of other pollutants, such as hydrocarbons (e.g., motor oil and gasoline).

4.3.11.3 Pollutant Removal Capabilities

Porous paver systems provide for the infiltration of stormwater runoff and they have a high removal rate of soluble pollutants. Pollutants become trapped and are then absorbed or broken down in the underlying soil layers. However, due to the potential for clogging, porous paver surfaces shall **not** be used for the removal of sediment or other particulate pollutants.

4.3.11.4 Application and Feasibility Criteria

Modular porous paver systems are typically used in low-traffic areas, such as:

- parking pads in parking lots;
- overflow parking areas;
- residential driveways;
- residential street parking lanes;
- recreational trails;
- golf cart and pedestrian paths; and
- emergency vehicle and fire access lanes.

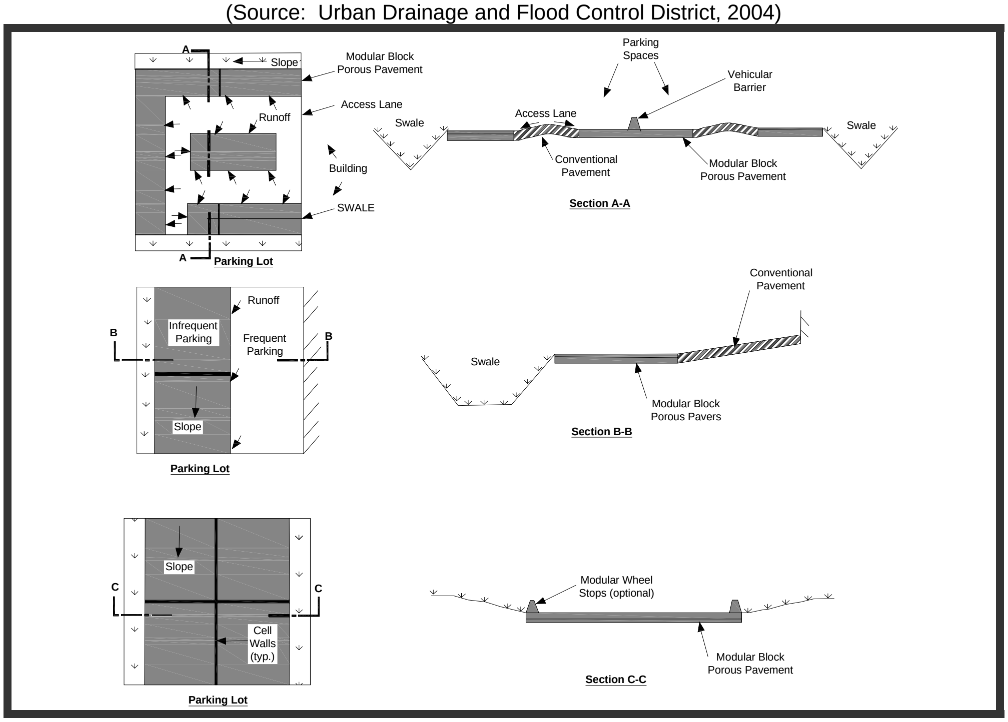
Porous paver systems shall not be used in high traffic areas due to the potential for cell compaction and failure. Examples of paver systems that have been used for some of the above listed applications are presented in Figures 4-46 and 4-47.

Figure 4-46. Examples of Porous Paver Surfaces

(Sources: Invisible Structures, Inc.; EP Henry Corp.)

Figure 4-47. Typical Modular Porous Paver System Applications

(Source: Urban Drainage and Flood Control District, 2004)



4.3.11.5 Planning and Design Standards

The design standards for modular porous paver systems are presented below. Design specifications developed by a commercial vendor for prefabricated proprietary systems can also be utilized, but must be approved where such specifications differ and/or are less stringent from the standards presented below. The local jurisdiction shall have the authority to require additional design conditions if deemed necessary.

<u>A. CONSTRUCTION SEQUENCING</u>

- Ideally, the construction of the porous paver system should take place **after** the construction site has been stabilized.
- In the event that the system is not constructed after site stabilization, care should be taken during construction to minimize the compaction of the soil in the area of the porous paver system and the deposition of sediments from disturbed, unstabilized areas to the system after its installation.
- Diversion berms and erosion prevention and sediment controls shall be maintained around the paver system area during all phases of construction. No runoff or sediment shall enter the area prior to completion of construction and the complete stabilization of construction areas.
- Porous paver systems shall not be used as a temporary sediment trap for construction activities.
- During and after excavation of the area where the porous paver system will be located, all excavated materials shall be placed downstream, away from the porous paver location, to prevent redeposition of the material during runoff events.

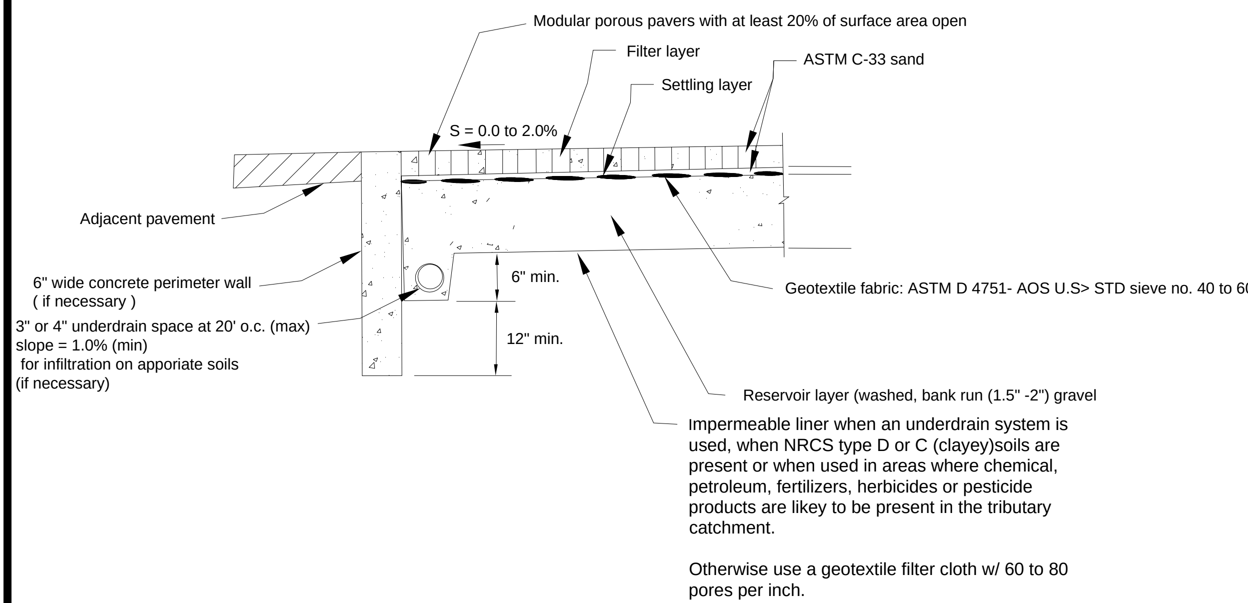
<u>B. LOCATION AND SITING</u>

- The use of porous paver systems is limited to low traffic volume areas, such as those identified above, that have a minimum soil infiltration rate of 0.5 in/hr, if an underdrain system is not present.
- Geotechnical testing of potential installation sites is required to verify an acceptable infiltration rate.
- Modular porous paver systems shall **<u>not</u>** be located:
  - ➢Within four (4) feet above bedrock or the seasonally high water level;
  - ➢Within 100 feet of a well;
  - ➢Within ten (10) feet of a building foundation that is above the proposed porous paver area or 100 feet from a building foundation that is below the proposed porous paver location;
  - ➢Within close proximity of sources of contaminants such as gas stations; and,
  - ➢On slopes greater than 5%.
- Because porous paver systems are not stormwater control devices, ideally, the area where the porous paver system is located should not receive stormwater runoff discharges from other areas. However, if that situation cannot be avoided, pretreatment of the discharges must be performed to remove sediment and other solids that can clog the porous paver system. Further, stormwater runoff discharging to the paver system area must flow into the area in a manner that will not cause damage to, or undermine, the porous paver system. Low velocity, unchannelized discharges are most favorable.
- Each paver area shall be placed in an easement that is recorded with the deed. The easement shall be defined as the outer edge of the paver area.

<u>C. PHYSICAL SPECIFICATIONS / GEOMETRY</u>

Several options exist for the top layer or surface of modular porous paver systems. The top layer should be chosen depending on strength required due to traffic loads, infiltration needs, and the manufacturer's recommendations. However, the sub-layers are generally similar, consisting of four to five layers as shown in Figure 4-48. Descriptions of each layer shown in Figure 4-48 are presented below:

Figure 4-48. Modular Porous Pavement Layers
(Source: Urban Drainage and Flood Control District, 2004)



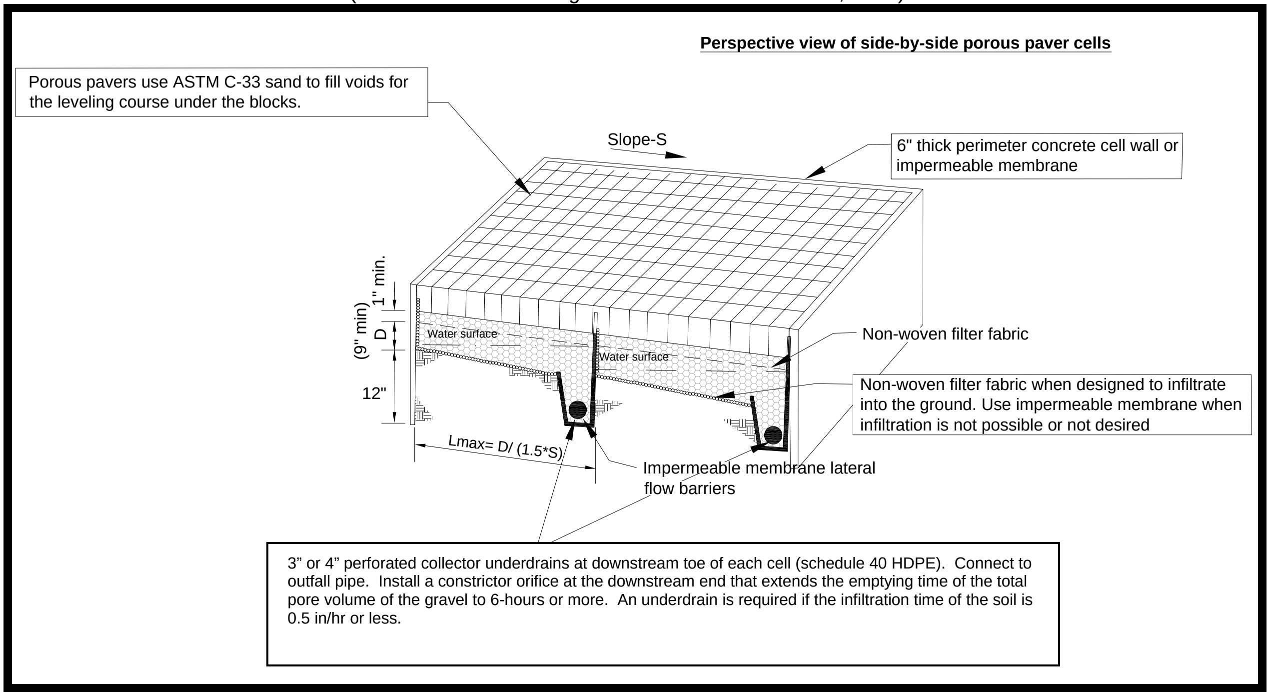
- The *Modular Porous Paver Layer* shall consist of a modular pavement grid of plastic, concrete, or brick and an aggregate or a vegetation medium. The depth of this layer shall be 2 to 8 inches deep depending on required bearing strength, pavement design requirements, and manufacturer's specifications.
- The *Settling Layer* shall consist of a 0.5-inch diameter crushed stone to a depth of 1 to 2 inches. This layer serves to stabilize the porous asphalt or concrete layer and can be combined with the reservoir layer using suitable stone.
- The *Reservoir Layer* (or Open Graded Base Material) shall consist of washed, bank-run gravel, 1.5 to 2.5 inches in diameter with a void space of about 40%. The depth of this layer depends on the desired storage volume, which is a function of the soil infiltration rate and void spaces, but typically ranges from two to four feet. The layer must have a minimum depth of 9 inches. The layer shall be designed to drain completely in 48 hours and to store, at a minimum, the WQv. Aggregate contaminated with soil is prohibited for use in this layer. The aggregate reservoir layer can be avoided or minimized if the subgrade is sandy and there is adequate time to infiltrate the necessary runoff volume into the sandy soil without by-passing the water quality volume. Consult the manufacturer's specifications to determine the appropriate layer design.
- The *Bottom Filter Layer* (not shown in diagram) is not always required. In cases where infiltration needs to be increased, a 6 inch layer of sand or a 2 inch thick layer of 0.5 inch crushed stone can be installed. The layer shall be graded to be completely flat to promote infiltration across the entire surface. This layer serves to stabilize the reservoir layer, to protect the underlying soil from compaction, and act as the interface between the reservoir layer and the filter fabric covering the underlying soil.
- A *Lateral Flow Barrier* as shown in Figure 4-49 is recommended around the modular porous paver area to prevent flow of water downstream and then surfacing at the toe of the porous paver installation. If the porous paver system is large enough, it may be divided into cells with cut-off barriers (also called cell walls) having a maximum distance (L_{max}) between them that shall not exceed:

Equation 4.3.11.1

$$L_{max} = \frac{D}{1.5S}$$

where: L_{max} = Maximum distance between cut-off membrane normal to the flow (ft)
S = Slope of the reservoir layer (ft/ft)
D = Depth of reservoir layer (ft)

Figure 4-49. Schematic of Lateral Flow Barriers
(Source: Urban Drainage and Flood Control District, 2004)



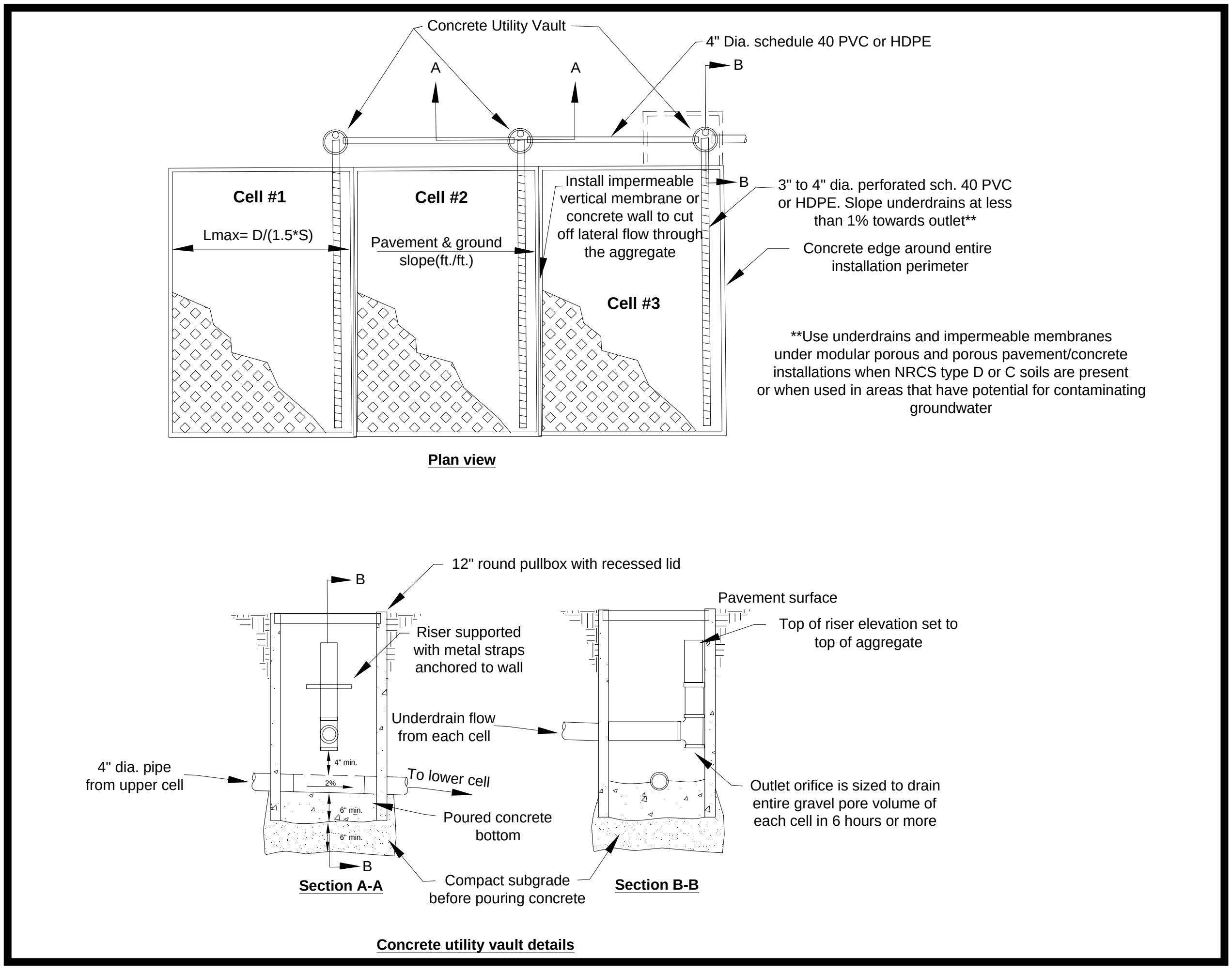
- *Filter Fabric* serves to inhibit soil from migrating into the reservoir and reducing storage capacity. The entire trench area, including the sides, shall be lined with filter fabric prior to placement of the aggregate.
- The *Underlying Soil* shall have an infiltration capacity of at least 0.5-inches/hour, but preferably greater than 0.5-inches/hour when an underdrain system is not present. Soils at the lower end of this range may not be suited for a full infiltration system or may require additional infiltration measures such as a perforated pipe or additional sand layer. Test borings are recommended to determine the soil classification, seasonal high ground water table elevation, and impervious substrata, and an initial estimate of permeability.
- The *Underdrain System* (if required) shall be designed per the modular porous paver system manufacturers' recommendation or a typical underdrain schematic. An underdrain system is shown in Figure 4-50.

D. PRETREATMENT

- Stormwater runoff that discharges to the modular porous paver system from surrounding areas require pretreatment to remove sediment and debris. Pretreatment can be provided by a sediment forebay or equivalent upstream pretreatment. A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to run-on to the area covered by porous pavers.

  If a sediment forebay is used, it shall be sized to contain 0.1 inch per impervious acre (363 ft^3) of contributing drainage and shall be no more than 6 feet deep. The pretreatment storage volume is part of the total WQv design requirement and may be subtracted from the WQv calculated for the site.

Figure 4-50. Schematic of an Underdrain System
(Source: Urban Drainage and Flood Control District, 2004)



E. OUTLET STRUCTURES

- If an underdrain is incorporated into the design, an outlet pipe shall be provided from the underdrain system to the local stormwater conveyance system. Discharges shall not exit the outlet pipe in an erosive manner. Due to the slow rate of discharge, outlet erosion protection is generally unnecessary for modular porous pavement systems.

F. MAINTENANCE ACCESS

- A minimum 20’ wide maintenance right of way or easement shall be provided from a driveway, public or private road. The maintenance access easement shall have a minimum unobstructed drive path width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.

G. LANDSCAPING

- Porous paver systems can be designed with a grass cover to aid in pollutant removal and prevent clogging. The grass should be capable of withstanding traffic and parking requirements, and frequent periods of inundation and drought.
- Ideally, landscaped areas that may discharge, or are adjacent to, the porous paver system should consist largely of grassy vegetation and have no exposed soil. Mulch, sticks, and leaves are debris that can clog the surface of the paver system, reducing its ability to infiltrate stormwater runoff and potentially affecting the structural integrity of the system. If such landscaped areas are utilized near

the paver system, care should be taken to design and maintain the landscaped area in a manner and frequency that prevents such debris from entering the paver area, or ensures frequent removal of such debris from the area. For example, maintenance practices should increase during the fall to remove leaves from the paver system if deciduous trees are located near the system.

H. SPECIAL CONSIDERATIONS FOR THE AS-BUILT CERTIFICATION AND PLANS/PLATS

- Because the use of the modular porous paver area reduces the WQv for the site and provides for stormwater treatment of some pollutants, the area must be shown on the as-built certification and the final plat specifically as a water quality BMP. The following components must be addressed in the as-built certification and final plat:

  1. The boundaries of the porous pavement area; clearly identified with a note that states "Do not pave over this area. Only porous pavement is allowed in this area".
  2. Clear identification of the manufacturer and type of paver system used.
  3. A copy of the manufacturer's specifications for the design and installation of the system.
  4. The underdrain design and specifications (if an underdrain is utilized).

This space intentionally left blank

This page left intentionally blank

4.3.11.6 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.11.6 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective use of porous paver systems as stormwater best management practices. It is the responsibility of the property owner to maintain all stormwater facilities in accordance with the minimum design standards and other guidance provided in this manual. The local jurisdiction has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for porous paver systems, along with a suggested frequency for each activity. Individual porous paver systems may have more, or less, frequent maintenance needs, depending upon a variety of factors including traffic volume, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain porous paver systems properly at all times.

Inspection Activities	Suggested Schedule
• Determine if the porous paver surface is free of sediment and debris (e.g., mulch, leaves, trash, etc.). • Determine if standing water exists for long periods of time after a storm event.	As needed
• Check that stormwater is not stored in the paver system longer than 48 hours after a storm. • Inspect vegetated areas that drain to the paver system and the paver system itself for evidence of erosion.	Monthly
• Inspect the surface of the paver system for structural integrity, deterioration, compaction, or spalling.	Annually
Maintenance Activities	**Suggested Schedule**
• Ensure that contributing area and porous paver surface are clear of debris (e.g., mulch, leaves, trash, etc.). • Stabilize (i.e., cover exposed soil) vegetated areas that discharge, or are adjacent to, the porous paver system. Grassy areas should be fully vegetated and mowed, with grass clippings removed. Landscaped areas should be designed and/or maintained such that they will not discharge debris (e.g., mulch, leaves) to the paver system, or that such debris is removed often.	As needed
• Vacuum sweep porous paver surface to keep free of sediment.	Quarterly
• Repair or reinstall the porous paver system, including the top and base course.	As needed

Additional Maintenance Considerations and Requirements

- Additional maintenance requirements for a porous paver system should be obtained from the manufacturer of the system and included in the Operations and Maintenance Plan for the site.
- The local jurisdiction encourages the use of the inspection checklist presented below for guidance in the inspection and maintenance of the porous paver system. Additional items should be added to the list, based on the inspection and maintenance information provided by the manufacturer of the pavers. The local jurisdiction can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the unit. Questions regarding inspection and maintenance should be referred to the local jurisdiction.

INSPECTION CHECKLIST – POROUS PAVEMENT SYSTEMS

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: ___________ Time: ______________ Site conditions:______________________________________

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Signs of clogging (e.g., standing water)?		
Debris (e.g., mulch, trash) accumulation?		
Sediment accumulation?		
Standing water?		
Erosion from paver system underdrain?		
Exposed soil in areas discharging or adjacent to the paver system?		
Other (describe)?		
Other (describe)?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:_________________________ Inspector Name (printed)_________________________

4.3.11.7 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

City of Knoxville. *Knoxville Best Management Practices Manual.* City of Knoxville Stormwater Engineering Division, March 2003.

City of Nashville, Tennessee. *Metropolitan Nashville and Davidson County Stormwater Management Manual, Volume 4 Best Management Practices.* 2006.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

Metropolitan Council. *Minnesota Urban Small Sites BMP Manual.* Metropolitan Council Services, St. Paul Minnesota, 2001.

Urban Drainage and Flood Control District, Denver, Colorado. *Urban Storm Drainage Criteria Manual – Volume 3 – Best Management Practices – Stormwater Quality.* 2004

4.3.11.8 Suggested Reading

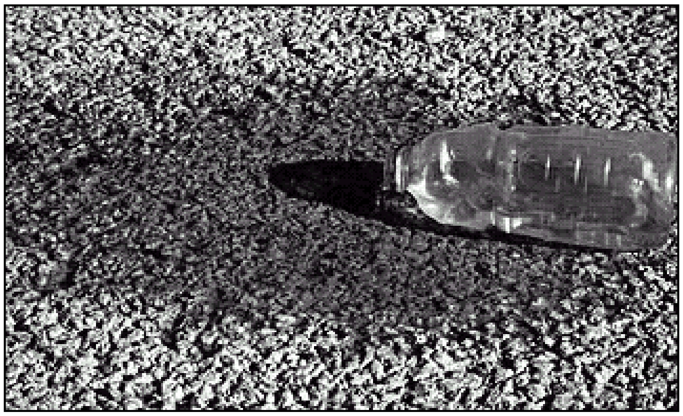
California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

US EPA. *Storm Water Technology Fact Sheet: Modular Treatment Systems.* EPA 832-F-99-044, Office of Water, 1999.

This page left intentionally blank

4.3.12 Porous Pavement

General Application
Water Quality BMP



Description: Infiltration practices that are alternatives to traditional asphalt and concrete surfaces. Stormwater runoff is infiltrated into the ground through a permeable layer of pavement and is naturally filtered.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Design considerations are similar to any paved area (soil properties, load-bearing design, hydrologic design of pavement and subgrade).
- Soil infiltration rate of 0.5 in/hr or greater is required if no underdrain is present.
- Soil groups "D" and "C" typically require and underdrain.
- Not appropriate for heavy or high traffic areas.
- Not appropriate as a water quality treatment BMP for drainage discharged from other areas.

ADVANTAGES / BENEFITS:

- Reduces runoff volume, attenuates peak runoff rate and outflow.
- Can be used as pretreatment for other BMPs for pollutants other than TSS.
- High level of pollutant removal for pollutants other than TSS.

DISADVANTAGES / LIMITATIONS:

- Sediment-laden runoff can clog porous pavement causing failure.
- Subgrade cannot be overly compacted.
- Construction must be sequenced to avoid compaction and clogging of pavement.

MAINTENANCE REQUIREMENTS:

- Vacuum to increase porous pavement life and avoid clogging.
- Ensure that contributing area is clear of debris and areas of erosion.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**No**
Detention/Retention:	**No**

Accepts hotspot runoff: *Yes, but does not provide stormwater treatment.*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**Med - High**
Maintenance Burden:	**Med**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	✷
Commercial/Industrial Use:	✷

✷ in certain situations

POLLUTANT REMOVAL

Total Suspended Solids:	**0%**

(Porous pavement is not considered a water quality removal BMP, but is used to reduce impervious area and therefore reduces the volume required for treatment.)

4.3.12.1 General Description

Porous pavement is a paved concrete or asphalt driving surface that permits the infiltration of water through the pavement and into the underlying soil. When considering the post-development stormwater runoff from a site, porous pavement is a best management practice (BMP) that allows a developed land surface to "appear" more like undeveloped land – runoff volumes and peak discharges of stormwater runoff from a developed site with porous pavement will be less than on a site without porous pavement. Porous pavement is an excellent application to reduce the effective impervious area on a site, therefore, reducing the design volumes and peak discharges that must be controlled. This will allow a reduction in the cost of other stormwater infrastructure, a fact that may offset the greater placement cost somewhat. Porous pavement can also eliminate problems with standing water, provide for groundwater recharge, control erosion of streambeds and riverbanks, facilitate pollutant removal, reduce thermal pollution of receiving waters, and provide for a more aesthetically pleasing site. **Porous pavement is not a BMP that can be used to remove total suspended solids (TSS).**

There are two types of porous pavement: porous asphalt and pervious concrete. Porous asphalt pavement consists of open-graded coarse aggregate, bonded together by asphalt cement, with sufficient interconnected voids to make it highly permeable to water. Pervious concrete consists of a specially formulated mixture of Portland cement, uniform, open-graded coarse aggregate, and water. Pervious concrete has enough void space to allow rapid percolation of water through the pavement. The void space in pervious concrete is in the 15%-22% range compared to 3%-5% for conventional pavements. The permeable surface is placed over a layer of open-graded gravel and crushed stone. The void spaces in the stone act as a storage reservoir for runoff. Pervious concrete is considered to be more durable than porous asphalt and is thought to have a greater ability than pervious asphalt to maintain its porosity in hot weather.

Porous pavements are best applied in areas that experience low vehicular traffic including parking lots and overflow parking areas; portions of streets such as residential parking lanes; driveways; plazas; and pedestrian or golf cart paths. Porous pavements are not recommended, and will not be approved, for use on driving surfaces that experience high traffic volume, heavy loads, and sediment-laden traffic (e.g., construction areas, dump sites).

A drawback to porous pavement is the cost and complexity of it compared to conventional pavements. Porous pavement requires a very high level of construction workmanship to ensure that it functions as designed. Like any BMP, porous pavement can fail, either for use as a driving/parking surface or an impervious area reduction measure, when improperly designed, constructed, or used. Past failures of porous pavement have been attributed to poor design, inadequate construction techniques, soils with low permeability, heavy vehicular traffic, and poor maintenance (USEPA, 1999). This measure, if used, should be monitored and maintained over the life of the development.

Porous pavement is designed primarily for impervious area reduction and the subsequent reduction in stormwater treatment volumes and peak discharges, particularly for smaller storm events. For some smaller sites, trenches can be designed to capture and infiltrate the water quality volume (WQv), and in some cases, the channel protection volume (CPv). Modifications or additions to the standard design presented in this section have been used to pass flows and volumes in excess of the WQv, or to increase storage capacity or treatment. These include:

- placing a perforated pipe near the top of the crushed stone reservoir to pass excess flows after the reservoir is filled;
- providing surface detention storage in a parking lot, adjacent swale, or detention basin with suitable overflow conveyance;
- connecting the stone reservoir layer to a stone filled trench;
- adding a sand layer and perforated pipe beneath the stone layer for filtration of the water quality volume; or,
- placing an underground detention tank or vault system beneath the layers.

Porous pavement has the positive characteristics of volume reduction due to infiltration, groundwater recharge, and an ability to blend into the normal urban landscape relatively unnoticed.

4.3.12.2 Stormwater Management Suitability

Water Quality (WQv)

Porous pavement is designed solely for impervious area reduction and water quality treatment of pollutants other than TSS. Porous pavements shall not be used for TSS removal. These pavements require some pretreatment BMP such as a filter strip for runoff entering the pavement to prevent clogging from sediment.

4.3.12.3 Pollutant Removal Capabilities

Porous pavement has a high removal of soluble pollutants, where they become trapped, absorbed or broken down in the underlying soil layers. However, due to the potential for clogging, porous pavement surfaces shall **not** be used for the removal of sediment or other particulate pollutants.

4.3.12.4 Application and Feasibility Criteria

Porous pavement is applicable only for use in low-traffic areas that do not encounter heavy loads and/or sediment-laden traffic or runoff, such as:

- parking pads in parking lots;
- overflow parking areas;
- residential driveways;
- residential street parking lanes;
- recreational trails;
- golf cart and pedestrian paths; and,
- emergency vehicle and fire access lanes.

4.3.12.5 Planning and Design Standards

The design standards for porous pavement are presented below. Design specifications developed by a commercial vendor for prefabricated proprietary systems can also be utilized, but must be approved where such specifications differ and/or are less stringent from the standards presented below. The local jurisdiction shall have the authority to require additional design conditions if deemed necessary.

A. CONSTRUCTION SEQUENCING

- Ideally, the construction of the porous pavement should take place after the construction site has been stabilized.
- In the event that the pavement is not constructed after site stabilization, care should be taken during construction to minimize the compaction of the soil in the area of the porous pavement and the deposition of sediments from disturbed, unstabilized areas.
- Diversion berms and erosion prevention and sediment controls shall be maintained around the porous pavement area during all phases of construction. No runoff or sediment shall enter the area prior to completion of construction and the complete stabilization of construction areas.
- Porous pavement shall not be used as a temporary sediment trap for construction activities.
- During and after excavation of the porous pavement area, all excavated materials shall be placed downstream, to prevent redeposition of the material during runoff events.

B. LOCATION AND SITING

- Suitable sites for porous pavement are limited to low traffic volume areas with a minimum soil infiltration rate of 0.5 in/hr without an underdrain system. Ideally, the soil should allow the entire runoff capture volume to be discharged from the porous pavement within 24 to 48 hours.

- Geotechnical testing of the proposed installation site is required to verify an acceptable infiltration rate.
- Porous pavement shall **not** be located:
  - Within four (4) feet above bedrock or the seasonally high water level;
  - Within 100 feet of a well;
  - Within ten (10) feet of a building foundation that is above the proposed porous pavement area or 100 feet from a building foundation that is below the proposed porous pavement location;
  - Within close proximity of sources of contaminants such as gas stations; and,
  - On slopes greater than 5%.
- Ideally, slopes should be flat or nearly flat to facilitate infiltration as opposed to runoff.
- The seasonally high water table or bedrock should be at least two feet below the bottom of the gravel layer if infiltration is to be relied on to remove the stored volume.
- Because porous pavement is not a stormwater control device, the area where the porous pavement is located should not receive stormwater runoff discharges from other areas. However, if that situation cannot be avoided, pretreatment of the discharges must be performed to remove sediment and other solids that can clog the porous pavement. Further, stormwater runoff discharging to the porous pavement area must flow into the area in a manner that will not cause damage to, or undermine, the porous pavement. Low velocity, unchannelized discharges are most favorable.
- Each porous pavement area shall be placed in an easement that is recorded with the deed. The easement shall be defined as the outer edge of the porous pavement.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

Porous asphalt or pervious concrete for the top layer or surface of the porous pavement should be chosen depending on strength required due to traffic loads, infiltration needs, and other site constraints. However, the sub-layers are generally similar, consisting of four to five layers as shown in Figure 4-51. The aggregate reservoir layer can sometimes be avoided or minimized if the subgrade is sandy and if there is adequate time to infiltrate the water quality volume into the sandy soil without bypassing any of the water quality volume. Descriptions of each of the layers is presented below.

- *Porous Pavement Layer* – This layer consists of a porous mixture of concrete or asphalt or a modular pavement grid of plastic, concrete, or brick and an aggregate or a vegetation medium. This layer is usually 2 to 4 inches deep depending on required bearing strength, pavement design requirements, and manufacturer's specifications.
- *Reservoir Layer or Open Graded Base Material* – The reservoir gravel base layer consists of washed, bank-run gravel, 1.5 to 2.5-inches in diameter with a void space of about 40%. The depth of this layer depends on the desired storage volume, which is a function of the soil infiltration rate and void spaces, but typically ranges from two to four feet. The layer must have a minimum depth of nine inches. The layer shall be designed to drain completely in 48 hours. If the porous pavement area is being utilized for stormwater quality treatment (for pollutants other than sediment/TSS), then the area must be designed to store, at a minimum, the WQv. Aggregate contaminated with soil shall not be used for the reservoir layer.
- *Bottom Filter Layer* – In cases where infiltration needs to be increased, a 6-inch layer of sand or a 2-inch thick layer of 0.5-inch crushed stone can be installed. The layer must be completely flat to promote infiltration across the entire surface. This layer serves to stabilize the reservoir layer, to protect the underlying soil from compaction, and act as the interface between the reservoir layer and the filter fabric covering the underlying soil.
- A *Lateral Flow Barrier -* as shown in Figure 4-52 is recommended around the porous pavement area to prevent flow of water downstream and then surfacing at the toe of the porous pavement installation. If the porous pavement area is large enough, it may be divided into cells with cut-off barriers having a maximum distance (L_{max}) between them that shall not exceed:

Equation 4.3.12.1

$$L_{\max} = \frac{D}{1.5S}$$

where: L_{max} = Maximum distance between cut-off membrane normal to the flow (ft)
S = Slope of the reservoir layer (ft/ft)
D = Depth of reservoir layer (ft)

Figure 4-51. Porous Pavement Layers
(Source: Urban Drainage and Flood Control District, 2004)

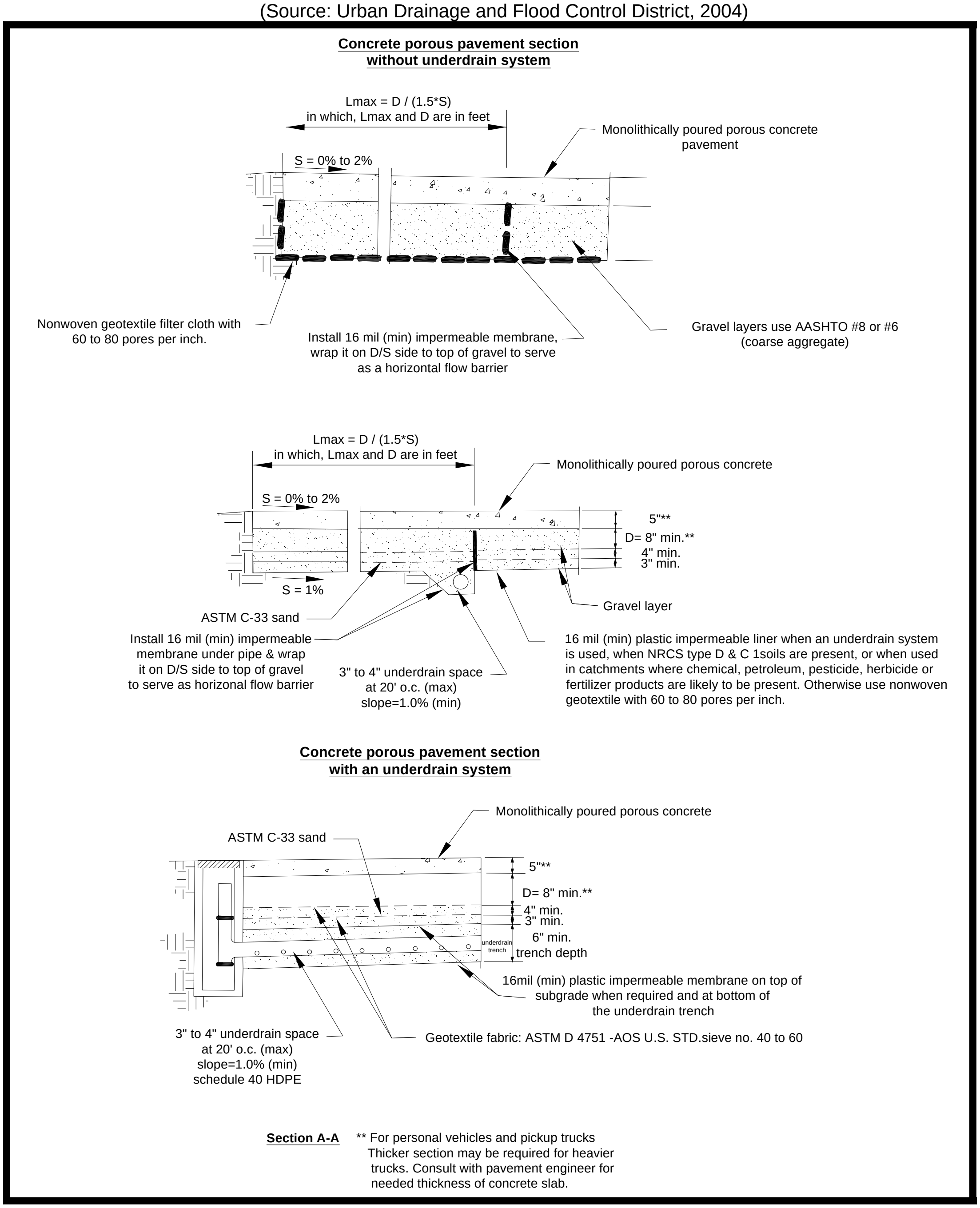
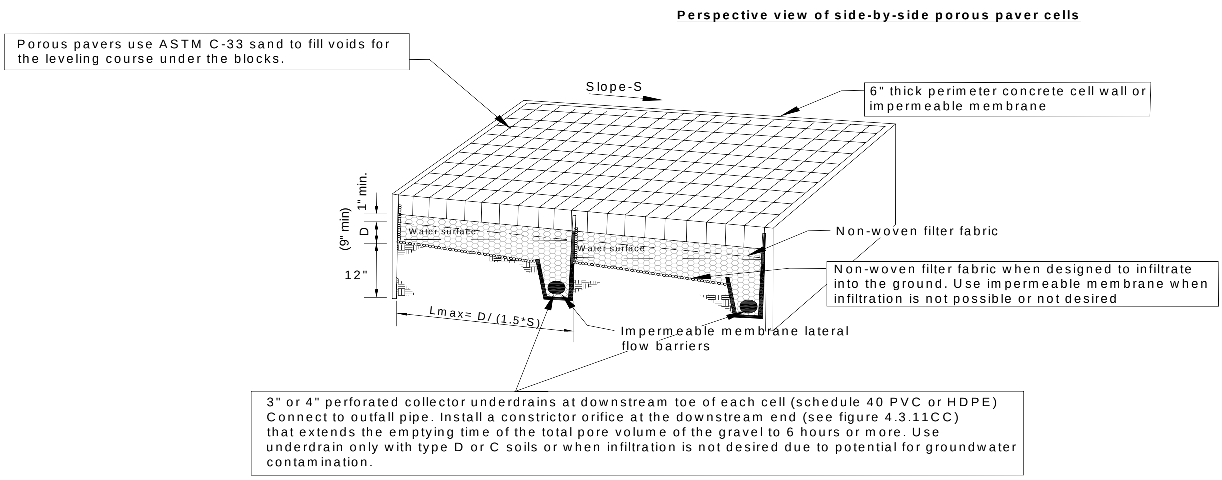


Figure 4-52. Schematic of Lateral Flow Barriers
(Source: Urban Drainage and Flood Control District, 2004)

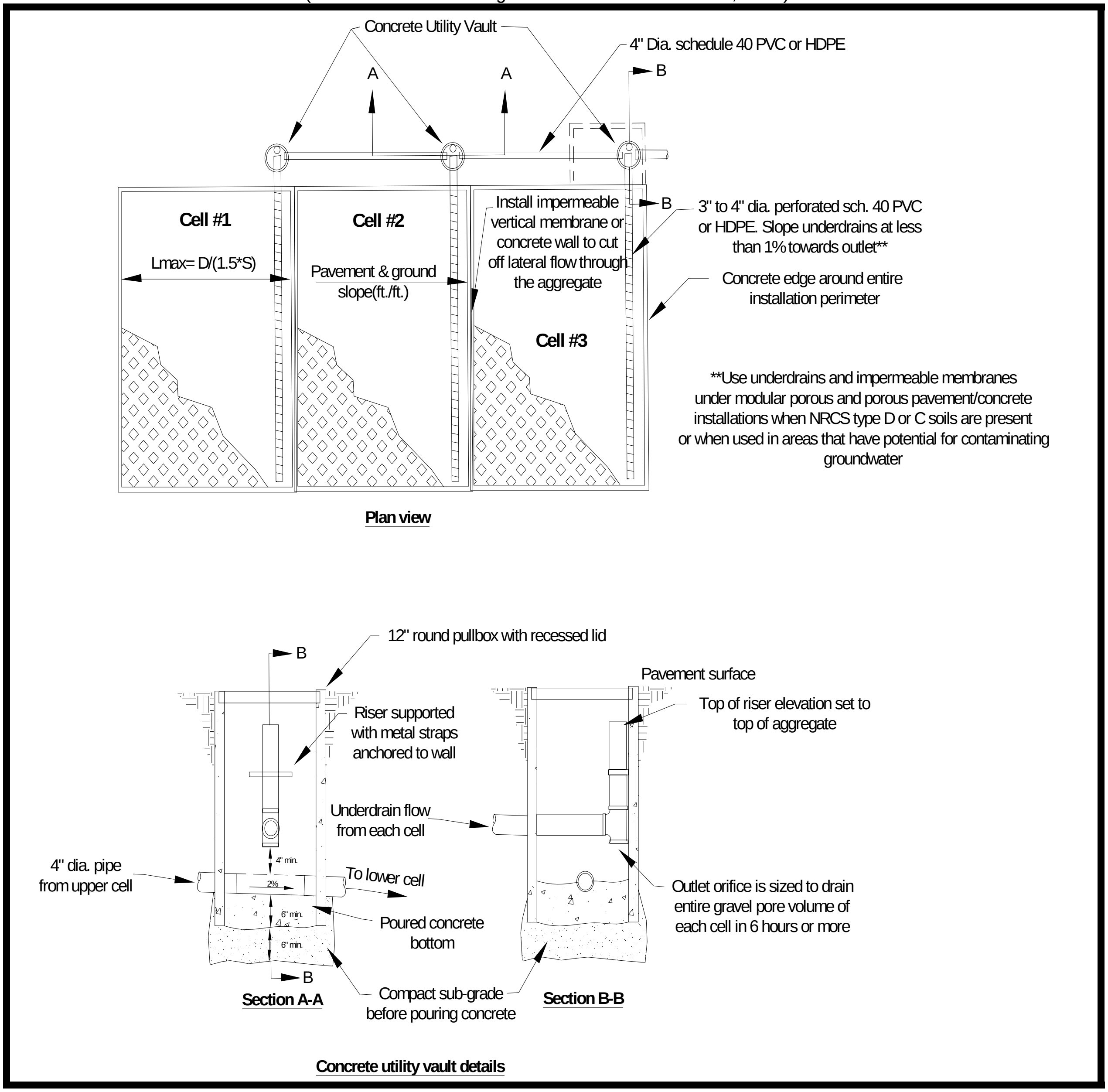


- *Filter Fabric* – It is very important to line the entire trench area, including the sides, with filter fabric prior to placement of the aggregate. The filter fabric serves to inhibit soil from migrating into the reservoir and reducing storage capacity.
- *Underlying Soil* – The underlying soil should have an infiltration capacity of at least 0.5-inches/hour but preferably greater than 0.5-inches/hour. Soils at the lower end of this range may not be suited for a full infiltration system or may require additional infiltration measures such as a perforated pipe or additional sand layer. Test borings are recommended to determine the soil classification, seasonal high ground water table elevation, and impervious substrata, and an initial estimate of permeability.
- The *Underdrain System* (if required) shall be designed per the porous pavement manufacturers' recommendation or through the use of another reference. A typical underdrain schematic is shown in Figure 4-53.

D. PRETREATMENT

- Although it is not recommended that runoff from other areas be discharged to the porous pavement area, stormwater runoff that discharges to the porous pavement system from surrounding areas requires pretreatment to remove sediment and debris. Pretreatment can be provided by a sediment forebay or equivalent upstream pretreatment. A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to run-on to the area covered by porous pavement.
- If a sediment forebay is used, it shall be sized to contain 0.1 inch per impervious acre (363 ft^3) of contributing drainage and shall be no more than 4 to 6 feet deep. The pretreatment storage volume is part of the total WQv design requirement and may be subtracted from the WQv calculated for the site.

Figure 4-53. Schematic of an Underdrain System
(Source: Urban Drainage and Flood Control District, 2004)



E. OUTLET STRUCTURES

- If an underdrain system is incorporated into the design, an outlet pipe shall be provided from the underdrain system to the local stormwater conveyance system. Discharges shall not exit the outlet pipe in an erosive manner. Due to the slow rate of discharge, outlet erosion protection is generally unnecessary for modular porous pavement systems.

F. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right-of-way or easement shall be provided from a driveway, public or private road. The maintenance access easement shall have a minimum unobstructed drive path width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.

G. LANDSCAPING

- Landscaped areas that may discharge, or are adjacent to, the porous pavement should consist largely of grassy vegetation and have no exposed soil. Mulch, sticks, and leaves are debris that can clog the surface of the porous pavement, reducing its ability to infiltrate stormwater runoff. If such landscaped areas are utilized near the porous pavement, care should be taken to design and maintain the landscaped area in a manner and frequency that prevents such debris from entering the porous pavement, or ensures frequent removal of such debris from the area. For example, maintenance practices should increase during the fall to remove leaves from the porous pavement if deciduous trees are located near the system.

H. SPECIAL CONSIDERATIONS FOR THE AS-BUILT CERTIFICATION AND PLANS/PLATS

- Because the use of porous pavement reduces the WQv for the site and provides for stormwater treatment of some pollutants, the area must be shown on the as-built certification and the final plat specifically as a water quality BMP. The following components must be addressed in the as-built certification and final plat:

    1. The boundaries of the porous pavement area; clearly identified with a note that states “Pervious pavement area. Do not pave with impervious pavement surfaces.”
    2. Clear identification of the type of porous pavement used.
    3. The underdrain design and specification (if an underdrain is utilized).

This space intentionally left blank

4.3.12.6 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.12.6 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective use of porous pavement as a stormwater best management practice. It is the responsibility of the property owner to maintain all stormwater facilities in accordance with the minimum design standards and other guidance provided in this manual. The local jurisdiction has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for porous pavement, along with a suggested frequency for each activity. Individual porous pavement applications may have more, or less, frequent maintenance needs, depending upon a variety of factors including traffic loads, the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain porous pavement properly at all times.

Inspection Activities	Suggested Schedule
• Ensure that the porous pavement surface is free of sediment and debris (e.g., mulch, leaves, trash, etc.). • Ensure that the contributing area upstream of the porous pavement surface is free of sediment and debris.	As needed
• Check to make sure that the porous pavement dewaters between storms.	Monthly
• Inspect the surface for structural integrity. Inspect for evidence of deterioration or spalling.	Annually
Maintenance Activities	**Suggested Schedule**
• Ensure that contributing area and porous pavement surface are clear of debris (e.g., mulch, leaves, trash, etc.). • Ensure that the contributing and adjacent area is stabilized and mowed, with clippings removed.	As needed, based on inspection
• Vacuum sweep porous pavement surface to keep free of sediment.	Typically three to four times a year
• Replace the porous pavement, including the top and base course, as needed.	Upon failure

The local jurisdiction encourages the use of the inspection checklist presented below for guidance in the inspection and maintenance of porous pavement. The local jurisdiction can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the unit. Questions regarding inspection and maintenance should be referred to the local jurisdiction.

INSPECTION CHECKLIST – POROUS PAVEMENT

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: ___________ Time: ______________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Signs of clogging (e.g., standing water)?		
Debris (mulch, trash) accumulation?		
Sediment accumulation?		
Standing water?		
Erosion from underdrain (if present)?		
Exposed soil in areas discharging or adjacent to the porous pavement area?		
Runoff discharge from pavement area 24 to 48 hours after the end of a storm event?		
Other (describe)?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:________________________________ Inspector Name (printed)________________________________

4.3.12.7 Example Installations

Figure 4-54. Porous Pavement Installation

Figure 4-55. Typical Porous Pavement Applications

(Photos by Bruce Ferguson, Don Wade)

4.3.12.8 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

City of Knoxville. *Knoxville Best Management Practices Manual.* City of Knoxville Stormwater Engineering Division, March 2003.

City of Nashville, Tennessee. *Metropolitan Nashville and Davidson County Stormwater Management Manual, Volume 4 Best Management Practices.* 2006.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

Metropolitan Council. *Minnesota Urban Small Sites BMP Manual.* Metropolitan Council Services, St. Paul Minnesota, 2001.

Urban Drainage and Flood Control District, Denver, Colorado. *Urban Storm Drainage Criteria Manual – Volume 3 – Best Management Practices – Stormwater Quality.* 2004

4.3.12.9 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

US EPA. *Storm Water Technology Fact Sheet: Modular Treatment Systems.* EPA 832-F-99-044, Office of Water, 1999.

4.4.1 Organic Filter

Limited Application Water Quality BMP

Description: The organic filter is a design variation of the surface sand filter that uses organic media to filter stormwater, as opposed to sand. An organic filter has two chambers. The first chamber is used for settling of heavy pollutant particles. The second chamber is filled with organic media and used to filter out fine particles.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Maximum drainage area of 10 acres.
- Minimum head requirement of 5 to 8 feet.
- Requires the use of a peat/sand mixture as the filter media.
- Runoff discharges to an underdrain system.
- Intended for hotspot or space-limited applications, or for areas requiring enhanced pollutant removal capability.

ADVANTAGES / BENEFITS:

- Useful for treatment of small drainage areas and highly impervious areas.
- Good retrofit capability.

DISADVANTAGES / LIMITATIONS:

- High installation and maintenance burden.
- Not recommended for areas that have high sediment content in stormwater or clay/silt runoff areas.
- Possible odor problems.
- Should be installed after site construction is complete.

MAINTENANCE REQUIREMENTS:

- Inspect for clogging.
- Remove sediment from forebay/chamber.
- Replace filter media as needed.
- Stabilize, clean and maintain upstream drainage areas.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	✷
Detention/Retention:	**No**

Accepts hotspot runoff: *Yes, but two feet of separation distance required to water table when used in hotspot areas*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**High**
Maintenance Burden:	**High**

LAND USE APPLICABILITY

Residential/Subdivision Use:	✷
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**80%**

✷ in certain situations, read further for more information

4.4.1.1 General Description

The organic filter is a design variant of the surface sand filter, which uses organic materials such as leaf compost or a peat/sand mixture as the filter media. The organic material enhances pollutant removal by providing adsorption of contaminants such as soluble metals, hydrocarbons, and other organic chemicals.

As with the surface sand filter, an organic filter consists of a pretreatment chamber, and one or more filter cells. Each filter bed contains a layer of leaf compost or the peat/sand mixture, followed by filter fabric and a gravel/perforated pipe underdrain system. The filter bed and subsoils can be separated by an impermeable polyliner or concrete structure to prevent movement into groundwater.

Organic filters are typically used in high-density applications, or for areas requiring enhanced pollutant removal ability. Maintenance is typically higher than the surface sand filter facility due to the need to reduce the potential for debris and sediment clogging the organic filter. In addition, organic filter systems have a higher head requirement than sand filters.

4.4.1.2 Stormwater Management Suitability

Organic filter systems are designed primarily as off-line systems for treatment of the water quality volume. They are not useful for flood protection and will typically need to be used in conjunction with another structural BMP, such as a conventional detention basin that can provide downstream channel protection, overbank flood protection, and extreme flood protection. Further, organic filter facilities must provide flow diversion and/or be designed to safely pass extreme storm flows and protect the filter bed and facility. Under certain circumstances, organic filters can provide limited runoff quantity control, particularly for smaller storm events.

Water Quality (WQv)
In organic filter systems, stormwater pollutants are removed through a combination of gravitational settling, filtration and adsorption. The filtration process effectively removes suspended solids and particulates, biochemical oxygen demand (BOD), fecal coliform bacteria, and other pollutants. Organic filters with a grass cover have additional opportunities for bacterial decomposition as well as vegetation uptake of pollutants, particularly nutrients.

Channel Protection (CPv)
For smaller sites, an organic filter may be designed to capture the entire channel protection volume (CPv) in either an off- or on-line configuration. Given that an organic filter system is typically designed to completely drain over 40 hours, the channel protection design requirement for extended detention of the 1-year, 24-hour storm runoff volume can be met. For larger sites or where only the WQv is diverted to the organic filter facility, another structural control must be used to provide extended detention of the CPv.

4.4.1.3 Pollutant Removal Capabilities

Peat/sand filter systems provide good removal of bacteria and organic waste metals. The total suspended solids design pollutant removal rate of 80% is a conservative average pollutant reduction percentage for design purposes derived from sampling data, modeling and professional judgment.

For additional information and data on pollutant removal capabilities for organic filters, see the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the International Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

4.4.1.4 Application and Site Feasibility Criteria

Organic filter systems are well-suited for highly impervious areas where land available for structural BMPs is limited. Organic filters should primarily be considered for new construction or retrofit opportunities for commercial, industrial, and institutional areas where the sediment load is relatively low, such as: parking lots, driveways, loading docks, gas stations, garages, airport runways/taxiways, and storage yards. Organic filters may also be feasible and appropriate in some multi-family residential developments where maintenance is performed by a landscaping (or other suitably capable) company.

To avoid rapid clogging and failure of the filter media, the use of organic filters should be avoided in areas with less than 50% impervious cover, or high sediment yield sites with clay/silt soils.

The following basic criteria should be evaluated to ensure the suitability of an organic filter facility for meeting stormwater management objectives on a site or development.

General Feasibility

- Not generally suitable for use in a residential subdivision.
- Suitable for use in high density/ultra urban areas.
- Not suitable for use as a regional stormwater control. On-site applications are typically most feasible.

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – Ten (10) acres maximum
- Space Required – Function of available head at site
- Minimum Head – The surface slope across the filter location should be no greater than 6%. The elevation difference needed at a site from the inflow to the outflow is 5 to 8 feet.
- Minimum Depth to Water Table – If used on a site with an underlying water supply aquifer, a separation distance of 2 feet required between the bottom of the organic filter and the elevation of the seasonally high water table to prevent groundwater contamination.
- Soils – Not recommended for drainage areas with exposed soil. Karst areas may require a liner.

Other Constraints / Considerations

- Aquifer Protection – Do not allow infiltration of filtered hotspot runoff into groundwater

4.4.1.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of organic filters. Organic filters that are not designed to these standards will not be approved. The local jurisdiction shall have the authority to require additional design conditions if deemed necessary.

A. CONSTRUCTION SEQUENCING

- Ideally, the construction of an organic filter shall take place **after** the construction site has been stabilized.
- In the event that the organic filter is not constructed after site stabilization, care shall be taken during construction to minimize the risk of premature failure of the organic filter due to deposition of sediments from disturbed, unstabilized areas.
- Diversion berms and erosion prevention and sediment controls shall be maintained around an organic filter during all phases of construction. No runoff or sediment shall enter the organic filter area prior to completion of construction and the complete stabilization of construction areas.
- Organic filters may be used as a temporary sediment trap for construction activities if all accumulated sediment is removed prior to media placement.
- During and after excavation of the organic filter, all excavated materials shall be placed downstream, away from the organic filters, to prevent redeposit of the material during runoff events.

B. LOCATION AND SITING

- Organic filter systems are generally applied to land uses with a high percentage of impervious surfaces. Organic filters shall not be utilized for sites that have less than 50% impervious cover. Pretreatment must be provided as described in part E below, due to the potential for high clay/silt sediment loads that could result in clogging and failure of the filter bed. Any disturbed or denuded areas located within the area draining to and treated by the organic filter shall be stabilized prior to construction and use of the organic filter.

- It is preferred that organic filters only be used in an off-line configuration where the WQv (and CPv if used for this purpose) is diverted to the filter facility through the use of a flow diversion structure and flow splitter. Stormwater flows greater than the WQv (and CPv if used for this purpose) are then diverted to other controls or downstream using a diversion structure or flow splitter.
- Organic filter systems shall be designed for intermittent flow and must be allowed to drain and re-aerate between rainfall events. They shall not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.
- Each organic filter shall be placed in an easement that is recorded with the deed. The easement shall be defined at the outer edge of the safety bench, or a minimum of 15 feet from the normal water pool elevation (measured perpendicular from the pool elevation boundary) if a safety bench is not included in the wetland design. Minimum setback requirements for the easement shall be as follows unless otherwise specified by the local jurisdiction:
  - From a property line – 10 feet;
  - From a public water system well – TDEC specified distance per designated category;
  - From a private well – 100 feet; if well is downgradient from a land use that requires a Special Pollution Abatement Permit, then the minimum setback is 250 feet;
    - From a septic system tank/leach field – 50 feet.

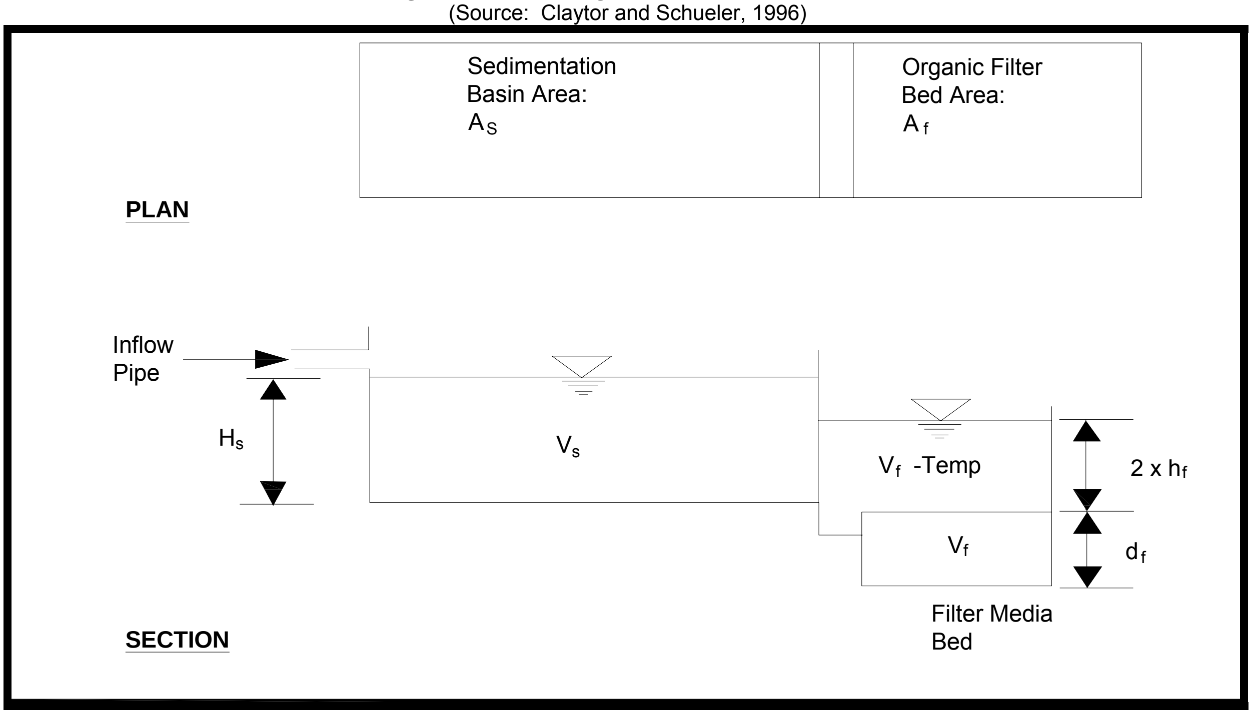
C. GENERAL DESIGN

- An organic filter facility shall consist of a two-chamber open-air structure, which is located at ground-level. The first chamber is the sediment forebay (commonly referred to as the sedimentation chamber) while the second chamber houses the filtration chamber (organic filter bed). Flow enters the sedimentation chamber where settling of larger sediment particles occurs. Runoff is then discharged from the sedimentation chamber through a perforated standpipe into the filtration chamber. After passing though the filter bed, runoff is collected by a perforated pipe and gravel underdrain system. Figure 4-58 provides a plan view and profile schematic of an organic filter.
- Organic filters can utilize a variety of organic materials as the filtering media. Two typical media bed configurations are the peat/sand filter and compost filter (see Figure 4-58). The peat filter includes an 18-inch 50/50 peat/sand mix over a 6-inch sand layer and can be optionally covered by 3 inches of topsoil and vegetation. The compost filter has an 18-inch compost layer.
- The type of peat used in a peat/sand filter is critically important. Fibric peat in which undecomposed fibrous organic material is readily identifiable is preferred. Hemic peat containing more decomposed material may also be used. Sapric peat made up of largely decomposed matter should *not* be used.

D. PHYSICAL SPECIFICATIONS / GEOMETRY

- The entire organic filter treatment system (including the sedimentation chamber) shall be designed to temporarily hold at least 75% of the WQv prior to filtration. Figure 4-56 illustrates the distribution of the treatment volume (0.75 WQv) among the various components of the surface sand filter, including:
  - V_s – volume within the sedimentation basin
  - V_f – volume within the voids in the filter bed
  - $V_{f\text{-}temp}$ – temporary volume stored above the filter bed
  - A_s – the surface area of the sedimentation basin
  - A_f – surface area of the filter media
  - h_s – height of water in the sedimentation basin
  - h_f – average height of water above the filter media
  - d_f – depth of filter media

Figure 4-56. Organic Filter Volumes
(Source: Claytor and Schueler, 1996)



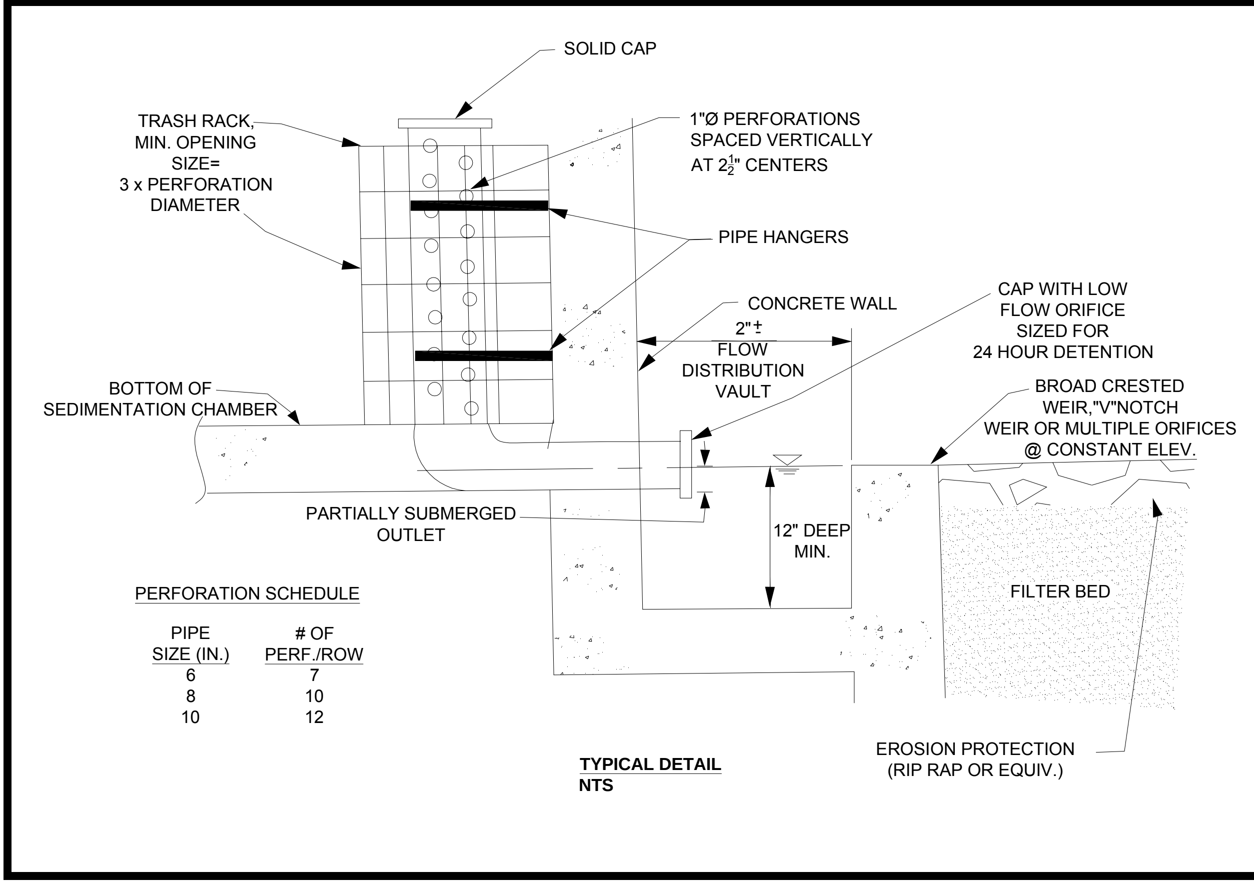
- The sedimentation chamber shall be sized to hold at least 25% of the computed WQv and have a length-to-width ratio of at least 2:1. Inlet and outlet structures should be located at opposite ends of the chamber.
- The filter area shall be sized based on the principles of Darcy's Law. A coefficient of permeability (k) of 3.5 ft/day for sand, 2.0 ft/day for peat and 8.7 ft/day for leaf compost shall be used. The filter bed shall be designed to completely drain in 40 hours or less.
- The filter media for an organic filter shall consist of either an 18" layer of peat/sand mixture on top of a 6" sand layer or an 18" layer of leaf compost. Both types of media are placed on top of the underdrain system. Three inches of topsoil shall be placed over the sand bed. Permeable filter fabric shall be placed both above and below the filter bed to prevent clogging of the filter media and the underdrain system. Figure 4-58 illustrates a typical media cross section.
- The filter bed shall be equipped with a 6-inch perforated pipe underdrain (PVC AASHTO M 252, HDPE, or other suitable pipe material) in a gravel layer. The underdrain shall have a minimum grade of 1/8-inch per foot (1% slope). Holes shall be 3/8-inch diameter and spaced approximately 6 inches on center. Gravel shall be clean-washed aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches with a void space of about 40%. Aggregate contaminated with soil shall not be used.
- The structure of the organic filter may be constructed of impermeable media such as concrete, or through the use of excavations and earthen embankments. When constructed with earthen walls/embankments, filter fabric shall be used to line the bottom and side slopes of the structures before installation of the underdrain system and filter media.

E. PRETREATMENT / INLETS

- Pretreatment of runoff in an organic filter system shall be by a sedimentation chamber, designed in accordance with the criteria stated above.
- Energy dissipators shall be used at the inlets to organic filters. Figure 4-57 shows a typical inlet pipe from the sedimentation basin to the filter media basin for the surface sand filter which can be also be utilized for an organic filter.

- The organic filter shall be designed such that runoff exits the sedimentation chamber at a non-erosive velocity.

Figure 4-57. Organic Filter Perforated Stand-Pipe
(Source: Claytor and Schueler, 1996)



F. OUTLET STRUCTURES

- An outlet pipe shall be provided from the underdrain system to the facility discharge. Due to the slow rate of filtration, outlet protection is generally unnecessary (except for emergency overflows and spillways). However, the design shall ensure that the discharges from the underdrain system occur in a non-erosive manner.

G. EMERGENCY SPILLWAY

- An emergency spillway shall be included per regulations of the local jurisdiction.

H. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right-of-way or drainage easement shall be provided for the organic filter from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles. Adequate access must be provided to the filter bed. Facility designs must enable maintenance personnel to easily remove and replace upper layers of the filter media.

I. SAFETY FEATURES

- Where necessary, surface organic filter facilities can be fenced to prevent access.
- Inlets and outlets shall be designed and maintained so as not to permit access by children.

J. LANDSCAPING

- Organic filters can be designed with a grass cover to aid in pollutant removal and prevent clogging. The grass should be capable of withstanding frequent periods of inundation and drought.

K. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

Physiographic Factors - Local terrain design constraints

- Low Relief – Use of an organic filter may be limited by low head
- High Relief – Filter bed surface must be level
- Karst – Use liner or impermeable membrane to seal bottom earthen surface of the organic filter or use watertight structure

Special Downstream Watershed Considerations

- Wellhead Protection – Reduce potential groundwater contamination (in required wellhead protection areas) by preventing infiltration of hotspot runoff. May require liner for type "A" and "B" soils; Pretreat hotspots; provide 2 to 4 foot separation distance from water table.

4.4.1.6 Design Procedures

Step 1. Compute runoff control volumes

Calculate WQv and CPv in accordance with the guidance presented in Chapter 3. Consult local regulations for peak discharge control (i.e., detention) requirements.

Step 2. Determine if the development site and conditions are appropriate for the use of organic filter.

Consider the subsections 4.4.1.4 and 4.4.1.5.K. Check with local jurisdiction agencies as appropriate to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 3. Compute WQv peak discharge (Q_{wq})

The peak rate of discharge for water quality design storm is needed for sizing of off-line diversion structures (see Chapter 3 for more information on this calculation).

(a) Using WQv, compute CN

(b) Compute time of concentration using TR-55 method

(c) Determine appropriate unit peak discharge from time of concentration

(d) Compute Q_{wq} (in inches) from unit peak discharge, drainage area, and WQv

Step 4. Size flow diversion structure, if needed

A flow regulator (or flow splitter diversion structure) should be supplied to divert the WQv to the organic filter facility. Size low flow orifice, weir, or other device to pass Q_{wq}.

Step 5. Size filtration basin chamber

The filter area is sized using the following equation (based on Darcy's Law):

$$A_f = (WQv)\,(d_f) / [(k)\,(h_f + d_f)\,(t_f)]$$

where:

WQv = water quality volume (ft^3)
A_f = surface area of filter bed (ft^2)
d_f = filter bed depth
(at least 1.5 feet, no more than 2 feet)
k = coefficient of permeability of filter media (ft/day)
(use 3.5 ft/day for sand)

(use 2.0 ft/day for peat)
(use 8.7 ft/day for leaf compost)

h_f = average height of water above filter bed (ft)
(1/2 h_{max}, which varies based on site but h_{max} is typically $\leq$ 6 feet)

t_f = design filter bed drain time (days)
(1.67 days or 40 hours is required maximum time)

Set preliminary dimensions of filtration basin chamber.

Step 6. Size sedimentation chamber

The sedimentation chamber shall be sized to at least 25% of the computed WQv and have a length-to-width ratio of 2:1. The Camp-Hazen equation is used to compute the required surface area:

$$A_s = -(Q_o/w) * \text{Ln}(1-E)$$

where:

A_s = sedimentation basin surface area (ft^2)
Q_o = rate of outflow = the WQv (ft^3) / 86400 seconds
w = particle settling velocity (ft/sec)
E = trap efficiency

Assuming:

- 90% sediment trap efficiency (0.9)
- particle settling velocity (ft/sec) = 0.0033 ft/sec for imperviousness (I) ≥ 75%
- particle settling velocity (ft/sec) = 0.0004 ft/sec for imperviousness (I) < 75%
- average of 24 hour holding period

Then:

A_s = (0.0081) (WQv) ft^2 for I ≥ 75%
A_s = (0.066) (WQv) ft^2 for I < 75%

Set preliminary dimensions of sedimentation chamber.

Step 7. Compute V_{min}

$$V_{min} = 0.75 * WQv$$

Step 8. Compute storage volumes within entire facility and sedimentation chamber orifice size

Use the following equation:

$$V_{min} = 0.75\ WQv = V_s + V_f + V_{f\text{-}temp}$$

(1) Compute V_f = water volume within filter bed/gravel/pipe = $A_f * d_f * n$
Where: n = porosity = 0.4 for most applications

(2) Compute $V_{f\text{-}temp}$ = temporary storage volume above the filter bed = $2 * h_f * A_f$

(3) Compute V_s = volume within sediment chamber = $V_{min} - V_f - V_{f\text{-}temp}$

(4) Compute h_s = height in sedimentation chamber = V_s/A_s

(5) Ensure h_s and h_f fit available head and other dimensions still fit – change as necessary in design iterations until all site dimensions fit.

(6) Size orifice from sediment chamber to filter chamber to release V_s within 24-hours at average release rate with 0.5 h_s as average head.

(7) Design outlet structure with perforations allowing for a safety factor of 10.

(8) Size distribution chamber to spread flow over filtration media – level spreader weir or orifices.

Step 9. Design inlets, pretreatment facilities, underdrain system, and outlet structures

See design criteria above for more details.

Step 10. Compute overflow weir sizes

1. Size overflow weir at elevation h_s in sedimentation chamber (above perforated stand pipe) to handle surcharge of flow through filter system from 25-year storm.

2. Plan inlet protection for overflow from sedimentation chamber and size overflow weir at elevation h_f in filtration chamber (above perforated stand pipe) to handle surcharge of flow through filter system from 25-year storm (see example).

This space intentionally left blank

This page left intentionally blank

4.4.1.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.4.1.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of an organic filter as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local jurisdiction has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for organic filters, along with a suggested frequency for each activity. Individual organic filters may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the organic filter in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• A record should be kept of the dewatering time (i.e., the time required to drain the filter bed completely after a storm event) for an organic filter to determine if maintenance is necessary. The filter bed should drain completely in about 40 hours after the end of the rainfall. • Check to ensure that the filter surface does not clog after storm events.	After Rain Events
• Check the contributing drainage area, facility, inlets and outlets for debris. • Check to ensure that the filter surface is not clogging.	Monthly
• Check to see that the filter bed is clean of sediment and the sediment chamber is not more than 50% full of sediment or the sediment accumulation is not more than 6 inches, whichever is less sediment. Remove sediment as necessary. • Make sure that there is no evidence of deterioration, spalling, bulging, or cracking of concrete. • Inspect inlets, outlets and overflow spillway to ensure good condition and no evidence of erosion. • Check to see if stormwater flow is bypassing the facility. • Ensure that no noticeable odors are detected outside the facility.	Annually
Maintenance Activities	**Suggested Schedule**
• Mow and stabilize (prevent erosion, vegetate denuded areas) the area draining to the organic filter. Collect and remove grass clippings. Remove trash and debris. • Ensure that activities in the drainage area minimize oil/grease and sediment entry to the system.	Monthly
• Check to see that the filter bed is clean of sediment and the sediment chamber is not more than 50% full of sediment or the sediment accumulation is not more than 6 inches, whichever is less sediment. Remove sediment as necessary. • Repair or replace any damaged structural parts. • Stabilize any eroded areas.	Annually
• If filter bed is clogged or partially clogged, manual manipulation of the surface layer of filter media may be required. Remove the top few inches of filter media, roto-till or otherwise cultivate the surface, and replace with media meeting the design specifications. • Replace any filter fabric that has become clogged.	As needed

Use of the inspection checklist that is presented on the next page is encouraged to guide the property owner in the inspection and maintenance of organic filters. The local jurisdiction can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the organic filter. Questions regarding stormwater facility inspection and maintenance should be referred to the local jurisdiction.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
ORGANIC FILTER INSPECTION CHECKLIST

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: _________ Time: __________ Site conditions:______________________________________

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Organic Filter Inspection List		
Complete drainage of the filter in about 40 hours after a rain event?		
Clogging of filter surface?		
Clogging of inlet/outlet structures?		
Clogging of filter fabric?		
Filter clear of debris and functional?		
Leaks or seeps in filter?		
Obstructions of spillway(s)?		
Animal burrows in filter?		
Sediment accumulation in filter bed (less than 50% is acceptable)?		
Cracking, spalling, bulging or deterioration of concrete?		
Erosion in area draining to organic filter?		
Erosion around inlets, filter bed, or outlets?		
Pipes and other structures in good condition?		
Undesirable vegetation growth?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

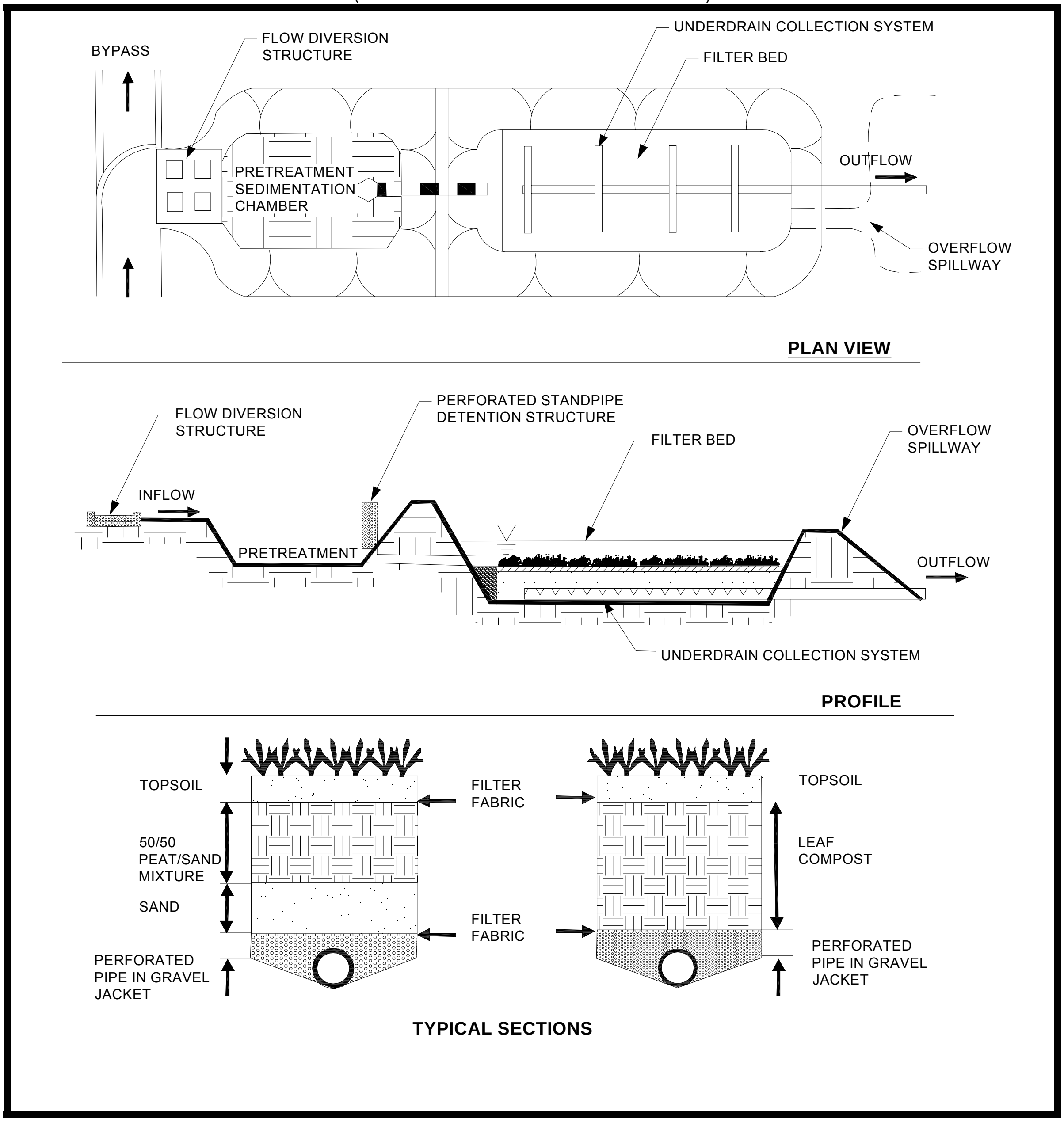
Corrective Action Needed	Due Date

Inspector Signature:______________________________ Inspector Name (printed)_________________________

4.4.1.8 Example Schematic

Figure 4-58. Schematic of an Organic Filter

(Source: Center for Watershed Protection)



4.4.1.9 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

City of Nashville, Tennessee. *Metropolitan Nashville and Davidson County Stormwater Management Manual, Volume 4 Best Management Practices.* 2006.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP). 2000.

Minnesota Pollution Control Agency. *Minnesota Stormwater Manual.* Accessed January 2006. http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html

Washington State Department of Ecology. *Stormwater Management Manual for Western Washington.* 2000.

4.4.1.10 Suggested Reading

Bell, W., L. Stokes, L.J. Gavan, and T. Nguyen. *Assessment of the Pollutant Removal Efficiencies of Delaware Sand Filter BMPs.* City of Alexandria, Department of Transportation and Environmental Services, Alexandria, VA, 1995.

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

Horner, R.R., and C.R. Horner. *Design, Construction, and Evaluation of a Sand Filter Stormwater Treatment System, Part II: Performance Monitoring.* Report to Alaska Marine Lines, Seattle, WA, 1995.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

Northern Virginia Regional Commission (NVRC). *The Northern Virginia BMP Handbook.* Annandale, VA, 1992.

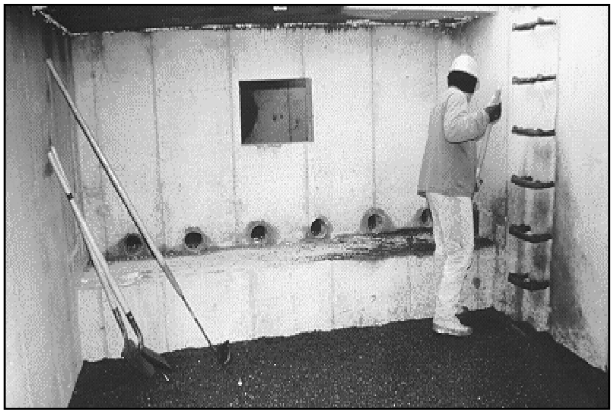
Schueler, T.R. *Developments in Sand Filter Technology to Improve Stormwater Runoff Quality.* Watershed Protection Techniques 1(2):47-54, 1994.

US EPA. *Storm Water Technology Fact Sheet: Sand Filters.* EPA 832-F-99-007, Office of Water. 1999.

Young, G.K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. *Evaluation and Management of Highway Runoff Water Quality.* FHWA-PD-96-032. Federal Highway Administration, Office of Environment and Planning, 1996.

4.4.2 Underground Sand Filter

**Limited Application
Water Quality BMP**



Description: The underground sand filter is a design variation of the surface sand filter, where the sand filter chambers and media are located in an underground vault.

KEY DESIGN CONSIDERATIONS

DESIGN GUIDELINES:

- Maximum contributing drainage area of 2 acres
- Typically requires 2 to 6 feet of head
- Precast concrete shells available, which decrease construction costs
- Underdrain required

ADVANTAGES / BENEFITS:

- High pollutant removal
- Applicable to small drainage areas
- Good for highly impervious areas
- Good retrofit capability

DISADVANTAGES / LIMITATIONS:

- High maintenance burden
- Not recommended for areas with high sediment content in stormwater or clay/silt runoff areas
- Possible odor problems
- Should be installed after site construction is complete

MAINTENANCE REQUIREMENTS:

- Inspect for clogging – rake first inch of sand
- Remove sediment from forebay/chamber
- Replace sand filter media as needed

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	✷
Detention/Retention:	**No**

Accepts hotspot runoff: *Yes, but requires impermeable liner and two feet of separation distance to water table when used in hotspot areas.*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**High**
Maintenance Burden:	**High**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**No**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**80%**

✷ in certain situations

4.4.2.1 General Description

The underground sand filter is a design variant of the surface sand filter. The underground sand filter is an enclosed filter system typically constructed just below grade in a vault along the edge of an impervious area such as a parking lot. The system consists of a sedimentation chamber and a sand bed filter. Runoff flows into the structure through a series of inlet grates located along the top of the control. Underground sand filters are best used for high-density land uses or ultra-urban applications where space for surface stormwater controls is limited. Figure 4-59 presents an example of an underground sand filter.

Figure 4-59. Example of an Underground Sand Filter

Multiple configurations have been developed for underground filters including the DC filter and the Delaware filter. The DC filter is intended to treat stormwater that is conveyed by a storm drain system. The Delaware filter (also known as the perimeter sand filter) is designed to collect flow directly from impervious surfaces and is well suited for installation along parking areas. Both systems operate in the same manner.

The underground sand filter is a three-chamber system. The initial chamber is a sedimentation (pretreatment) chamber that temporarily stores runoff and utilizes a wet pool to capture sediment. The sedimentation chamber is connected to the sand filter chamber by a submerged wall that protects the filter bed from oil and trash. The filter bed is 18 to 24 inches deep and may have a protective screen of gravel or permeable geotextile to limit clogging. The sand filter chamber also includes an underdrain system with inspection and clean out wells. Perforated drain pipes under the sand filter bed extend into a third chamber that collects filtered runoff. Flows beyond the filter capacity are diverted through an overflow weir.

Due to its location below the surface, underground sand filters have a high maintenance burden and should only be used where adequate inspection and maintenance can be ensured.

4.4.2.2 Stormwater Management Suitability

Underground sand filter systems are designed primarily as off-line systems for treatment of the water quality volume. They are not useful for flood protection and will typically need to be used in conjunction with another structural BMP, such as a conventional detention basin that can provide downstream channel protection, overbank flood protection, and extreme flood protection. Further, underground sand filter facilities utilized on-line must provide flow diversion and/or be designed to safely pass extreme storm flows and protect the filter bed and facility. Under certain circumstances, underground sand filters can provide limited runoff quantity control, particularly for smaller storm events.

Water Quality (WQv)
In underground sand filter systems, stormwater pollutants are removed through a combination of gravitational settling, filtration and adsorption. The filtration process effectively removes suspended solids and particulates, biochemical oxygen demand (BOD), fecal coliform bacteria, and other pollutants.

Channel Protection (CPv)
For smaller sites, an underground sand filter may be designed to capture the entire channel protection volume (CPv) in either an off- or on-line configuration. Given that an underground sand filter system is typically designed to completely drain over 40 hours, the channel protection design requirement for extended detention of the 1-year, 24-hour storm runoff volume can be met. For larger sites or where only the WQv is diverted to the underground sand filter facility, another structural control must be used to provide extended detention of the CPv.

4.4.2.3 Pollutant Removal Capabilities

Underground sand filters are presumed to be able to remove 80% of the total suspended solids (TSS) load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. Undersized or poorly designed underground sand filters can reduce TSS removal performance.

Additionally, research has shown that use of underground sand filters will have benefits beyond the removal of TSS, such as the removal of other pollutants (i.e. phosphorous, nitrogen, fecal coliform and heavy metals), as well, which is useful information should the pollutant removal criteria change in the future. The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data.

For additional information and data on pollutant removal capabilities for underground sand filters, see the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the International Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

4.4.2.4 Application and Site Feasibility Criteria

Underground sand filter systems are well-suited for highly impervious areas where land available for structural BMPs is limited. Underground sand filters should primarily be considered for new construction or retrofit opportunities for commercial, industrial, and institutional areas where the sediment load is relatively low, such as: parking lots, driveways, loading docks, gas stations, garages, airport runways/taxiways, and storage yards.

To avoid rapid clogging and failure of the filter media, the use of underground sand filters should be avoided in areas with less than 50% impervious cover, or high sediment yield sites with clay/silt soils.

The following basic criteria should be evaluated to ensure the suitability of an underground sand filter facility for meeting stormwater management objectives on a site or development.

General Feasibility

- Not suitable for use in a residential subdivision
- Suitable for use in high density/ultra-urban areas
- Not suitable for use as a regional stormwater control. On-site applications are typically most feasible.

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – 2 acres maximum for an underground sand filter
- Space Required – Function of available head at site
- Minimum Head – The surface slope across the filter location should be no greater than 6%. The elevation difference needed at a site from the inflow to the outflow is 2-6 feet.
- Minimum Depth to Water Table – If used on a site with an underlying water supply aquifer, a separation distance of 2 feet is required between the bottom of the sand filter and the elevation of the seasonally high water table to prevent groundwater contamination.
- Soils – Not recommended for clay/silt drainage areas that are not stabilized.

Other Constraints / Considerations

- Aquifer Protection – Do not allow infiltration of filtered hotspot runoff into groundwater

4.4.2.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of underground sand filters. Underground sand filters that are not designed to these standards will not be approved. The local jurisdiction shall have the authority to require additional design conditions if deemed necessary.

A. CONSTRUCTION SEQUENCING

- Ideally, the construction of an underground filter shall take place **after** the construction site has been stabilized.
- In the event that the underground sand filter is not constructed after site stabilization, care shall be taken during construction to minimize the risk of premature failure of the organic filter due to deposition of sediments from disturbed, unstabilized areas.
- Diversion berms and erosion prevention and sediment controls shall be maintained around the filter during all phases of construction. No runoff or sediment shall enter the sand filter area prior to completion of construction and the complete stabilization of construction areas.
- Underground sand filters may be used as a temporary sediment trap for construction activities if all accumulated sediment is removed prior to sand placement.
- During and after excavation of the underground sand filter area, all excavated materials shall be placed downstream, away from the sand filter, to prevent redeposit of the material during runoff events.

B. LOCATION AND SITING

- Underground sand filter systems are generally applied to land uses with a high percentage of impervious surfaces. Sand filters shall not be utilized for sites that have less than 50% impervious cover. Any disturbed or denuded areas located within the area draining to and treated by the underground sand filter shall be stabilized prior to construction and use of the sand filter.
- Delaware underground sand filters are typically sited along the edge, or perimeter, of an impervious area such as a parking lot.
- DC underground sand filters are installed within the storm drain system.
- Underground sand filter systems shall be designed for intermittent flow and must be allowed to drain and re-aerate between rainfall events. They shall not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.
- Each underground sand filter shall be placed in an easement that is recorded with the deed. The easement shall be defined at the outer edge of sand filter. Minimum setback requirements for the easement shall be as follows unless otherwise specified by the local jurisdiction:

- From a property line – 10 feet;
- From a public water system well – TDEC specified distance per designated category;
- From a private well – 100 feet; if well is downgradient from a land use that requires a Special Pollution Abatement Permit, then the minimum setback is 250 feet;
- From a septic system tank/leach field – 50 feet.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

- The entire treatment system (including the sedimentation chamber) must temporarily hold at least 75% of the WQv prior to filtration. Figures 4-60 and 4-61 illustrate the distribution of the treatment volume (0.75 WQv) among the various components of the underground sand filters, including:
  - V_w – wet pool volume within the sedimentation basin
  - V_f – volume within the voids in the filter bed
  - V_{temp} – temporary volume stored above the filter bed
  - A_s – the surface area of the sedimentation basin
  - A_f – surface area of the filter media
  - h_f – average height of water above the filter media (1/2 h_{temp})
  - d_f – depth of filter media

Figure 4-60. Underground (DC) Sand Filter Volumes
(Source: Center for Watershed Protection)

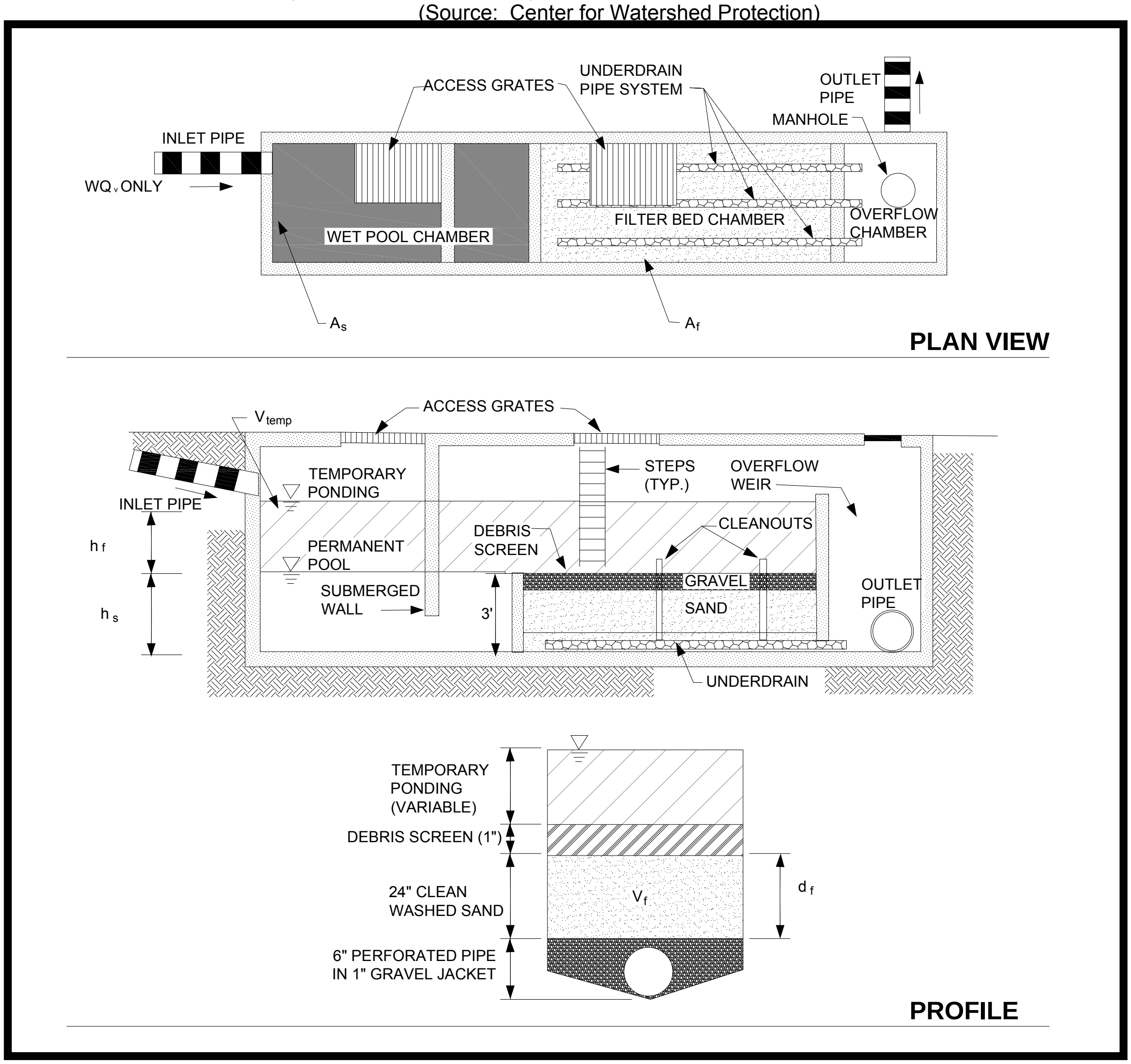
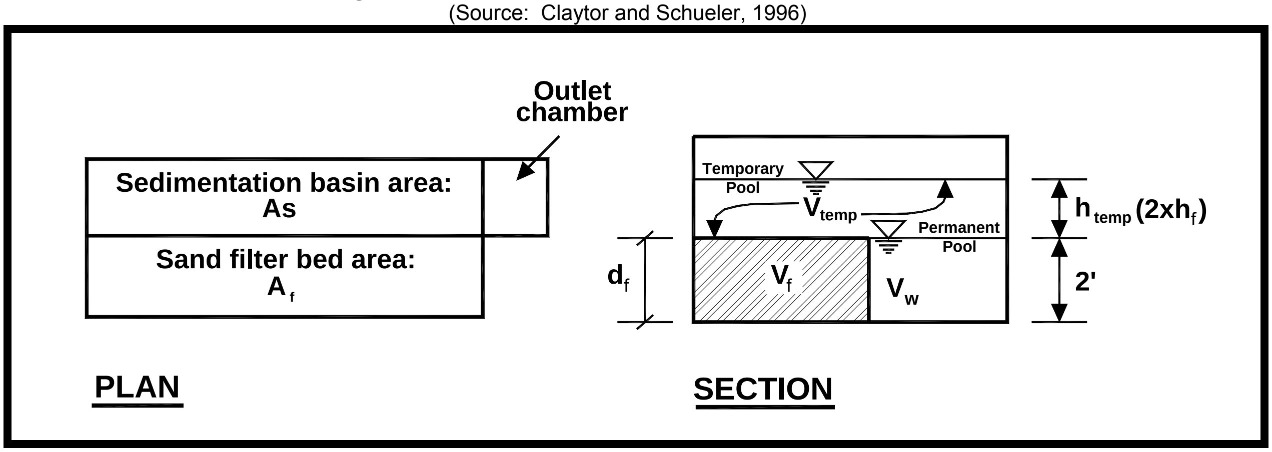


Figure 4-61. Perimeter Sand Filter Volumes
(Source: Claytor and Schueler, 1996)



- The sedimentation chamber shall be sized to at least 50% of the computed WQv.
- The filter area shall be sized based on the principles of Darcy's Law. A coefficient of permeability (k) of 3.5 ft/day for sand shall be used. The filter bed shall be designed to completely drain in 40 hours or less.
- The filter media shall consist of an 18-inch to 24-inch layer of clean washed medium aggregate concrete sand (ASTM C-33) on top of the underdrain system. Figure 4-62 illustrates a typical media cross section.
- The filter bed shall be equipped with a 6-inch perforated pipe underdrain (PVC AASHTO M 252, HDPE, or other suitable pipe material) in a gravel layer. The underdrain shall have a minimum grade of 1/8-inch per foot (1% slope). Holes shall be 3/8-inch diameter and spaced approximately 6 inches on center. Gravel shall be clean-washed aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches with a void space of about 40%. Aggregate contaminated with soil shall not be used.

D. OUTLET STRUCTURES

- An outlet pipe shall be provided from the underdrain system to the facility discharge. Due to the slow rate of filtration, outlet protection is generally unnecessary (except for emergency overflows and spillways). However, the design shall ensure that the discharges from the underdrain system occur in a non-erosive manner.

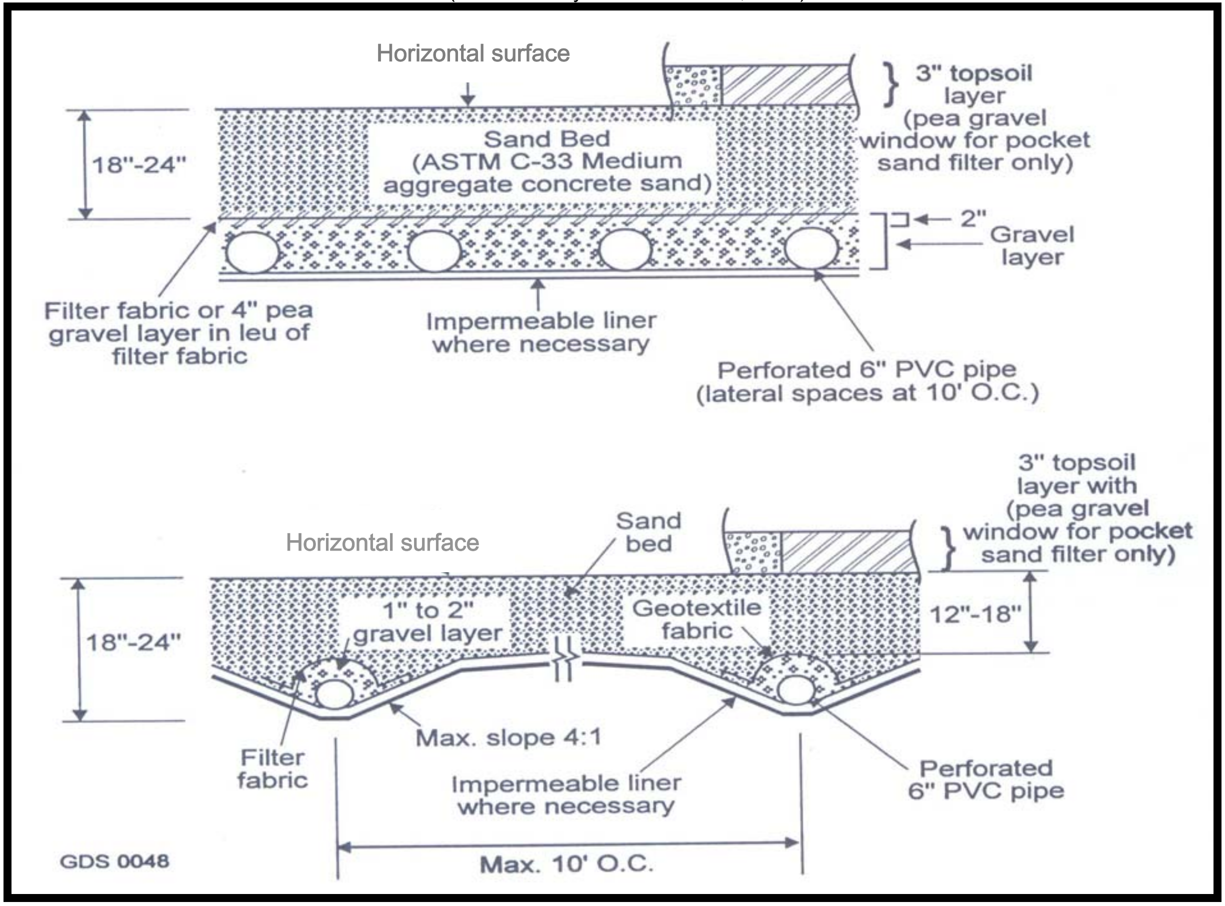
E. EMERGENCY SPILLWAY

- An emergency bypass spillway or weir must be included in the underground sand filter design to safely pass flows that exceed the WQv (and CPv if the filter is utilized for channel protection purposes

F. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right-of-way or drainage easement shall be provided for an underground sand filter from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles. Adequate access must be provided to the grates of the filter bed. Facility designs must enable maintenance personnel to easily remove and replace upper layers of the filter media.

Figure 4-62. Typical Sand Filter Media Cross Sections
(Source: Claytor and Schueler, 1996)



G. SAFETY FEATURES

- Inlets, access grates and outlets shall be designed and maintained so as not to permit access by children. Inlet and access grates to the underground sand filters may be locked.

4.4.2.6 Design Procedures

Step 1. Compute runoff control volumes

Calculate WQv, CPv in accordance with the guidance presented in Chapter 3.

Step 2. Determine if the development site and conditions are appropriate for the use of an underground sand filter.

Consider the subsection 4.4.2.4. Check with local jurisdiction and other agencies as appropriate to determine if there are any additional restrictions or watershed requirements that may apply.

Step 3. Compute WQv peak discharge (Q_{wq})

The peak rate of discharge for water quality design storm is needed for sizing of off-line diversion structures (see Chapter 3 for more information on this calculation).

(a) Using WQv, compute CN
(b) Compute time of concentration using TR-55 method
(c) Determine appropriate unit peak discharge from time of concentration
(d) Compute Q_{wq} in inches from unit peak discharge, drainage area, and WQv.

Step 4. Size flow diversion structure, (if needed)

If a diversion structure is utilized, a flow regulator should be supplied to divert the WQv to the underground sand filter facility. Size low flow orifice, weir, or other device to pass Q_{wq}.

Step 5. Size filtration basin chamber

The filter area is sized using the following equation (based on Darcy's Law):

$$A_f = (WQv)\,(d_f) / [(k)\,(h_f + d_f)\,(t_f)]$$

where:

A_f = surface area of filter bed (ft^2)
WQv = water quality volume (ft^3)
d_f = filter bed depth (1.5 ft)
(at least 18 inches, no more than 24 inches)
k = coefficient of permeability of filter media (ft/day)
(use 3.5 ft/day for sand)
h_f = average height of water above filter bed (ft)
(1/2 h_{max}, which varies based on site but h_{max} is typically $\leq$ 6 feet)
t_f = design filter bed drain time (days)
(1.67 days or 40 hours is required maximum time)

Set preliminary dimensions of filtration basin chamber.

Step 6. Size sedimentation chamber

Depending on the type of underground sand filter system utilized, the sedimentation chamber shall be sized to at least 50% of the computed WQv and have a length-to-width ratio of 2:1. The Camp-Hazen equation is used to compute the required surface area:

$$A_s = -(Q_o/w) * Ln\,(1-E)$$

where:

A_s = sedimentation basin surface area (ft^2)
Q_o = rate of outflow = the WQv (ft^3) / 86400 seconds
w = particle settling velocity (ft/sec)
E = trap efficiency

Assuming:

- 90% sediment trap efficiency (0.9)
- particle settling velocity (ft/sec) = 0.0033 ft/sec for imperviousness ≥ 75%
- particle settling velocity (ft/sec) = 0.0004 ft/sec for imperviousness < 75%
- average of 24 hour holding period

Then:

A_s = (0.0081) (WQv) ft^2 for I $\geq$ 75%
A_s = (0.066) (WQv) ft^2 for I < 75%

Set preliminary dimensions of sedimentation chamber.

Step 7. Compute V_{min}

$$V_{min} = 0.75 * WQv$$

Step 8. Compute storage volumes within entire facility and sedimentation chamber orifice size

Underground (D.C.) sand filter:

$$V_{min} = 0.75\ WQv = V_s + V_f + V_{f\text{-}temp}$$

(1) Compute V_f = water volume within filter bed/gravel/pipe = $A_f * d_f * n$
Where: n = porosity = 0.4 for most applications

(2) Compute $V_{f\text{-}temp}$ = temporary storage volume above the filter bed = $2 * h_f * A_f$

(3) Compute V_s = volume within sediment chamber = $V_{min} - V_f - V_{f\text{-}temp}$

(4) Compute h_s = height in sedimentation chamber = V_s/A_s

(5) Ensure h_s and h_f fit available head and other dimensions still fit – change as necessary in design iterations until all site dimensions fit.

(6) Size orifice from sediment chamber to filter chamber to release V_s within 24-hours at average release rate with 0.5 h_s as average head.

(7) Design outlet structure with perforations allowing for a safety factor of safety times the orifice capacity.

(8) Size distribution chamber to spread flow over filtration media – level spreader weir or orifices.

***Underground perimeter (Delaware) sand filter*:**

(1) Compute V_f = water volume within filter bed/gravel/pipe = $A_f * d_f * n$
where: A_f = surface area of filter bed (ft^2)
d_f = filter bed depth (1.5 ft)
(at least 18 inches, no more than 24 inches)
n = porosity = 0.4 for most applications

(2) Compute V_w = wet pool storage volume A_s * 2 feet minimum

(3) Compute V_{temp} = temporary storage volume = $V_{min} – (V_f + V_w)$

(4) Compute h_{temp} = temporary storage height = $V_{temp} / (A_f + A_s)$

(5) Ensure $h_{temp} \geq 2 * h_f$, otherwise decrease h_f and re-compute. Ensure dimensions fit available head and area – change as necessary in design iterations until all site dimensions fit.

(6) Size distribution slots from sediment chamber to filter chamber.

Step 9. Design inlets, underdrain system, and outlet structures

See design criteria above for more details.

Step 10. Compute overflow weir sizes

***Underground (D.C.) sand filter*:**

$$V_{min} = 0.75 \text{ WQv} = V_s + V_f + V_{f\text{-}temp}$$

(1) Compute V_f = water volume within filter bed/gravel/pipe = $A_f * d_f * n$
where: n = porosity = 0.4 for most applications

(2) Compute $V_{f\text{-}temp}$ = temporary storage volume above the filter bed = $2 * h_f * A_f$

(3) Compute V_s = volume within sediment chamber = $V_{min} - V_f - V_{f\text{-}temp}$

(4) Compute hs = height in sedimentation chamber = Vs/As

(5) Ensure hs and hf fit available head and other dimensions still fit – change as necessary in design iterations until all site dimensions fit.

(6) Size orifice from sediment chamber to filter chamber to release Vs within 24-hours at average release rate with 0.5 hs as average head.

(7) Design outlet structure with perforations allowing for a safety factor of times the orifice capacity.

(8) Size distribution chamber to spread flow over filtration media – level spreader weir or orifices.

Underground perimeter (Delaware) sand filter: Size overflow weir at end of sedimentation chamber to handle excess inflow, set at WQv elevation.

This space intentionally left blank

4.4.2.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.4.2.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of an underground sand filter as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local jurisdiction has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for underground sand filters, along with a suggested frequency for each activity. Individual filters may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the sand filter in proper operating condition at all times.

Inspection Activities	**Suggested Schedule**
• A record should be kept of the dewatering time (i.e., the time required to drain the filter bed completely after a storm event) for a sand filter to determine if maintenance is necessary. The filter bed should drain completely in about 40 hours after the end of the rainfall. • Check to ensure that the filter surface does not clog after storm events.	After Rain Events
• Check the contributing drainage area, facility, inlets and outlets for debris. • Check to ensure that the filter surface is not clogging.	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, bulging, or cracking of concrete. • Inspect grates of sand filter (perimeter and Delaware). • Inspect inlets, outlets and overflow spillway to ensure good condition and no evidence of erosion. • Check to see if stormwater flow is bypassing the facility (if so designed). • Ensure that no noticeable odors are detected outside the facility.	Annually
Maintenance Activities	**Suggested Schedule**
• Mow and stabilize (prevent erosion, vegetate denuded areas) the area draining to the underground sand filter. Collect and remove grass clippings. Remove trash and debris. • Ensure that activities in the drainage area minimize oil/grease and sediment entry to the system. • If permanent water level is present (perimeter and Delaware).in 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. • Repair or replace any damaged structural parts. • Stabilize any eroded areas.	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

Use of the inspection checklist that is presented on the next page is encouraged to guide the property owner in the inspection and maintenance of underground sand filters. The local jurisdiction can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the underground sand filter. Questions regarding stormwater facility inspection and maintenance should be referred to the local jurisdiction.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
UNDERGROUND SAND FILTER INSPECTION CHECKLIST

Location: ______________________________ Owner Change since last inspection? Y N
Owner Name, Address, Phone: ______________________________
Date: __________ Time: __________ Site conditions: ______________________________

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Underground Sand Filter Inspection List		
Complete drainage of the filter in about 40 hours after a rain event?		
Clogging of filter surface?		
Clogging of inlet/outlet structures?		
Clogging of filter fabric?		
Filter clear of debris and functional?		
Leaks or seeps in filter?		
Obstructions of spillway(s)?		
Animal burrows in filter?		
Sediment accumulation in filter bed (less than 50% is acceptable)?		
Cracking, spalling, bulging or deterioration of concrete?		
Erosion in area draining to sand filter?		
Erosion around inlets, filter bed, or outlets?		
Pipes and other structures in good condition?		
Undesirable vegetation growth?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

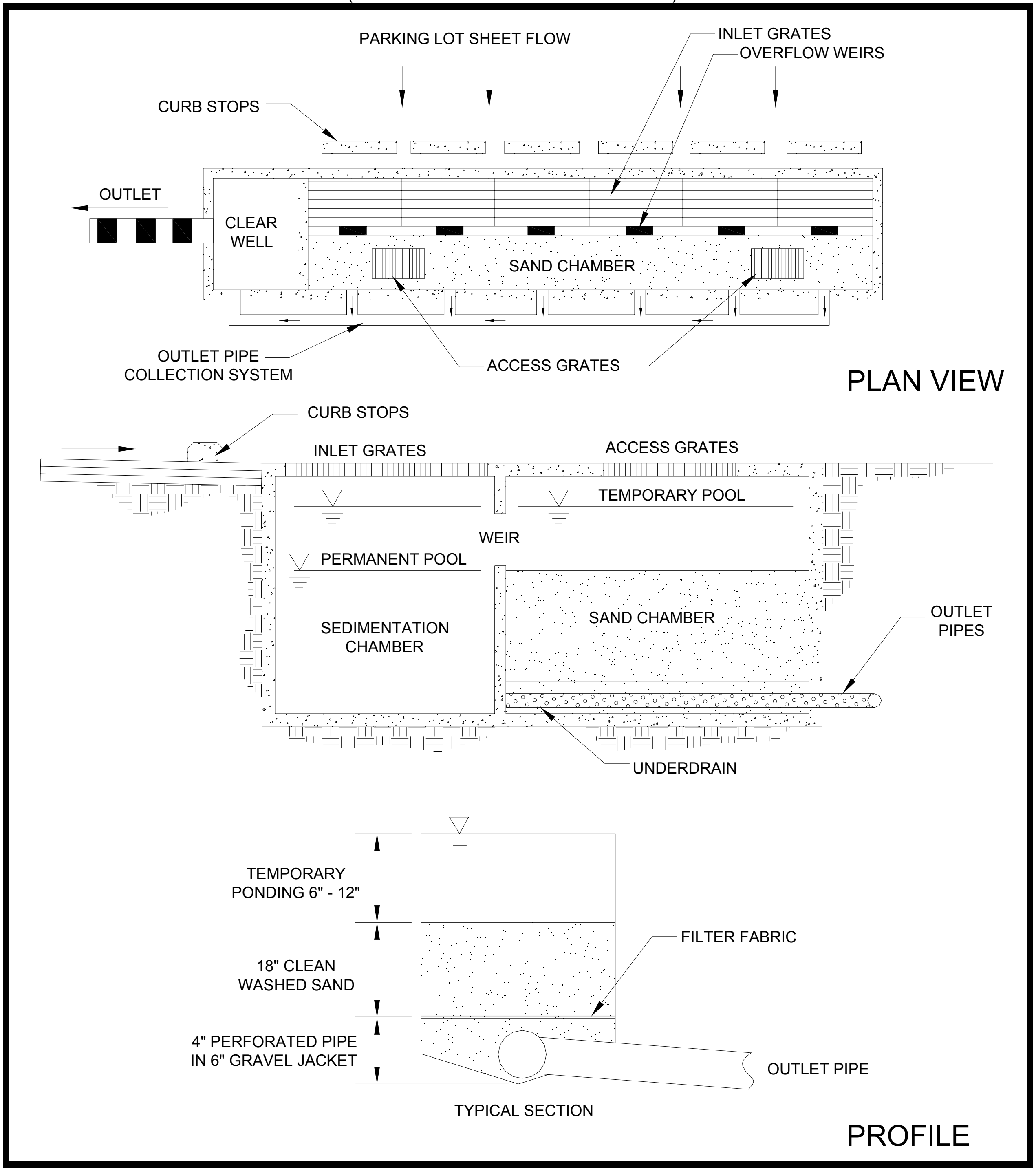
Corrective Action Needed	Due Date

Inspector Signature: ______________________ Inspector Name (printed) ______________________

4.4.2.8 Example Schematics

Figure 4-63. Schematic of a Perimeter (Delaware) Sand Filter

(Source: Center for Watershed Protection)



4.4.2.9 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook*. 2001.

Brown, W., and T. Schueler. *The Economics of Stormwater BMPs in the Mid-Atlantic Region.* Prepared for Chesapeake Research Consortium, Edgewater, MD, by the Center for Watershed Protection, Ellicott City, MD, 1997.

Center for Watershed Protection (CWP). *Design of Stormwater Filtering Systems.* Prepared for the Chesapeake Research Consortium, Solomons, MD, and U.S. EPA Region 5, Chicago, IL, by the Center for Watershed Protection, Ellicott City, MD, 1996.

Center for Watershed Protection (CWP). *Multi-Chamber Treatment Train developed for stormwater hot spots.* Watershed Protection Techniques 2(3):445-449, 1997.

City of Nashville, Tennessee. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

Maryland Department of the Environment (MDE). *Maryland Stormwater Design Manual.* 2000. Available at: http://www.mde.state.md.us/programs/waterprograms/sedimentandstormwater/stormwater_design/index.asp.

Minnesota Pollution Control Agency. *Minnesota Stormwater Manual.* Accessed January 2006. http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html

New Jersey Department of Environmental Protection. *Stormwater Best Management Practices Manual.* 2004.

Schueler, T. *Developments in Sand Filter Technology to Improve Stormwater Runoff Quality.* Watershed Protection Techniques 1(2):47-54, 1994.

StormwaterAuthority.com. *Sand and Organic Filters.* Accessed January 2006. www.stormwaterauthority.com

4.4.2.10 Suggested Reading

Bell, W., L. Stokes, L.J. Gavan, and T. Nguyen. *Assessment of the Pollutant Removal Efficiencies of Delaware Sand Filter BMPs.* City of Alexandria, Department of Transportation and Environmental Services, Alexandria, VA, 1995.

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks,* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

Horner, R.R., and C.R. Horner. *Design, Construction, and Evaluation of a Sand Filter Stormwater Treatment System. Part II: Performance Monitoring.* Report to Alaska Marine Lines, Seattle, WA, 1995.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone,* March, 1992.

Northern Virginia Regional Commission (NVRC). *The Northern Virginia BMP Handbook.* Annandale, VA, 1992.

US EPA. *Storm Water Technology Fact Sheet: Sand Filters.* EPA 832-F-99-007, Office of Water, 1999.

Young, G.K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. *Evaluation and Management of Highway Runoff Water Quality.* FHWA-PD-96-032, Federal Highway Administration, Office of Environment and Planning, 1996.

This page left intentionally blank

4.4.3 Submerged Gravel Wetland

**Limited Application
Water Quality BMP**

Description: Submerged gravel wetlands are one or more cells filled with crushed rock designed to support wetland plants. Stormwater flows subsurface through the root zone of the constructed wetland where pollutant removal takes place.

KEY DESIGN CONSIDERATIONS

DESIGN GUIDELINES:

- Intended for space-limited applications
- High removal rates for sediment, Biochemical Oxygen Demand, and fecal coliform bacteria
- Max drainage area ≤ 5 acres

ADVANTAGES / BENEFITS:

- High TSS removal
- Generally requires low land consumption, and can fit within an area that is typically devoted to landscaping
- High pollutant removal capabilities are expected; however, limited performance data exist
- Can be located in low-permeability soils with a high water table

DISADVANTAGES / LIMITATIONS:

- High maintenance burden
- Not recommended for areas with high sediment content in stormwater or clay/silt runoff areas
- Should be installed after site construction is complete

MAINTENANCE REQUIREMENTS:

- Periodic sediment removal required to prevent clogging of gravel base

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**No**
Detention/Retention:	**No**

Accepts hotspot runoff: *Yes, but requires an impermeable liner and two feet of separation distance to seasonal high water table when used in hotspot areas.*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**High**
Maintenance Burden:	**High**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**No**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**80%**

4.4.3.1 General Description

The submerged gravel wetland system consists of one or more treatment cells that are filled with crushed rock or gravel and is designed to allow stormwater to flow subsurface through the root zone of the constructed wetland. The outlet from each cell is set at an elevation to keep the rock or gravel submerged. Wetland plants are rooted in the media, where they can directly take up pollutants. In addition, algae and microbes thrive on the surface area of the rocks. In particular, the anaerobic conditions on the bottom of the filter can foster the denitrification process. Although widely used for wastewater treatment in recent years, only a handful of submerged gravel wetland systems have been designed to treat stormwater. Mimicking the pollutant removal ability of nature, this structural control relies on the pollutant-stripping ability of plants and soils to remove pollutants from runoff.

4.4.3.2 Stormwater Management Suitability

Submerged gravel wetlands are designed as off-line systems for treatment of the water quality volume. They are not useful for flood protection and will need to be used in conjunction with another structural BMP, such as a conventional detention basin that can provide downstream channel protection, overbank flood protection, and extreme flood protection. All submerged gravel wetlands must provide flow diversion to protect the gravel bed.

Water Quality (WQv)
In submerged gravel wetlands, stormwater runoff flows through a gravel filter with wetland plants at the surface. Pollutants are removed through biological activity on the surface of the gravel and pollutant uptake by the plants. This practice is fundamentally different from other wetland designs because while most wetland designs behave like wet ponds, with differences in grading and landscaping, gravel wetlands are similar to filtering practices. The filtration process effectively removes suspended solids and particulates, biochemical oxygen demand (BOD), fecal coliform bacteria, and other pollutants.

Channel Protection (CPv)
The WQv is diverted to the submerged gravel wetland; therefore, it requires the use of another structural BMP to provide CPv extended detention.

4.4.3.3 Pollutant Removal Capabilities

The pollution removal efficiency of the submerged gravel wetland is similar to a typical wetland. Due to the settling environment of the gravel media, recent data show a TSS removal rate in excess of the 80% goal. Therefore the total suspended solids design pollutant removal rate of 80% is a conservative average pollutant reduction percentage for design purposes derived from sampling data, modeling and professional judgment.

For additional information and data on pollutant removal capabilities for submerged gravel wetlands, see the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the International Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

4.4.3.4 Application and Site Feasibility Criteria

Submerged gravel wetlands are well-suited for highly impervious areas where land available for structural BMPs is limited. Submerged gravel wetlands should primarily be considered for new construction or retrofit opportunities for commercial, industrial, and institutional areas where the sediment load is relatively low, such as: parking lots, driveways, loading docks, gas stations, garages, airport runways/taxiways, and storage yards.

To avoid clogging, the use of submerged gravel wetlands should be avoided in areas with less than 50% impervious cover, or high sediment yield sites with clay/silt soils.

The following basic criteria should be evaluated to ensure the suitability of a submerged gravel wetland for meeting stormwater management objectives on a site or development.

General Feasibility

- Suitable for use in high density/ultra-urban areas
- Not suitable for use in a residential subdivision
- Not suitable for use as a regional stormwater control. On-site applications are typically most feasible.

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – 5 acres maximum for a submerged gravel wetland. Submerged gravel wetland systems need sufficient drainage area to maintain vegetation. See subsection 3.1.8 for guidance on performing a water balance calculation.
- Space Required – Function of drainage area and available head at site.
- Minimum Head – The local slope should be relatively flat (<2%). While there is no minimum slope requirement, there does need to be enough elevation drop from the inlet to the outlet to ensure that hydraulic conveyance by gravity is feasible (generally about 3 to 5 feet).
- Pretreatment – Submerged gravel wetland designs shall include a sediment forebay or other equivalent pretreatment measures to prevent sediment or debris from entering and clogging the gravel bed.
- Minimum Depth to Water Table – Unless they receive hotspot runoff, submerged gravel wetland systems can be allowed to intersect the groundwater table. If a submerged gravel wetland receives hotspot runoff and has an underlying water supply aquifer, a separation distance of 2 feet is required between the bottom of the gravel and the elevation of the seasonally high water table to prevent groundwater contamination.
- Soils – Not recommended for clay/silt drainage areas that are not stabilized.

Other Constraints / Considerations

- See subsection 4.3.4 (*Stormwater Wetlands*) for additional planning and design guidance.

4.4.3.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of submerged gravel wetlands. Submerged gravel wetlands that are not designed to these standards will not be approved. The local jurisdiction shall have the authority to require additional design conditions if deemed necessary.

A. LOCATION AND SITING

- Submerged gravel wetlands shall have a contributing drainage area of 5 acres or less.
- Submerged gravel wetlands are generally applied to sites that have greater than 50% impervious cover. Any disturbed or denuded areas located within the area draining to and treated by the submerged gravel wetland shall be stabilized prior to construction and use of the submerged gravel wetland.
- Each submerged gravel wetland shall be placed in an easement that is recorded with the deed. The easement shall be defined at the outer edge of submerged gravel wetland. Minimum setback requirements for the easement shall be as follows unless otherwise specified by the local jurisdiction:
    - From a property line – 10 feet;
    - From a public water system well – TDEC specified distance per designated category;
    - From a private well – 100 feet; if well is downgradient from a land use that requires a Special Pollution Abatement Permit, then the minimum setback is 250 feet;
    - From a septic system tank/leach field – 50 feet.

Manufactured (i.e., Proprietary) Submerged Gravel Wetlands:

- A manufacturer of a treatment system utilizing a submerged gravel wetland is identified below. Manufactured submerged gravel wetlands should be selected on the basis of good design, suitability for the desired pollution control goals, durabilty, ease of installation, ease of maintenance, and reliability. The product listed below is not the only product available, nor should its presence in this manual be construed as an endorsement of this product. It is merely shown as a manufactured submerged gravel wetland that is known to operate in the southeast.

StormTreat	www.stormtreat.com

B. PRETREATMENT / INLETS

- Sediment regulation and removal is critical to sustain submerged gravel wetlands. A gravel wetland facility shall have a sediment forebay or equivalent upstream pretreatment.
- A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to dispersal into the wetland. The forebay shall consist of a separate cell, formed by an acceptable barrier. A forebay shall be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the gravel wetland facility.
- The forebay shall be sized to contain 0.1 inches per impervious acre (363 ft^3) of contributing drainage and shall be no more than 4 to 6 feet deep. The pretreatment storage volume is part of the total WQv design requirement and may be subtracted from the WQv for wetland storage sizing.
- A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.
- Inflow channels shall be stabilized with flared riprap aprons, or the equivalent. Exit velocities from the forebay to the wetland shall be non-erosive.

C. OUTLET STRUCTURES

- An outlet pipe shall be provided from the submerged gravel wetland to the facility discharge. The design shall ensure that the discharges occur in a non-erosive manner.

D. MAINTENANCE ACCESS

- A minimum 20’ wide maintenance right-of-way or drainage easement shall be provided to a submerged gravel wetland from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.

E. LANDSCAPING

- A landscaping plan shall be developed that indicates the methods used to establish and maintain wetland coverage. Minimum considerations of the plan include: selection of plant species, planting plan and sources of plant material. More information on wetland plants can be found at the following websites:
  - http://wetlands.fws.gov/
  - http://www.npwrc.usgs.gov/resource/plants/floraso/species.htm
  - http://www.tva.gov/river/landandshore/stabilization/plantsearch.htm

4.4.3.6 Design Procedures

Step 1. Compute runoff control volumes

Calculate WQv and CPv in accordance with the guidance presented in Chapter 3. Consult local regulations for peak discharge control (i.e., detention) requirements.

Step 2. Determine if the development site and conditions are appropriate for the use of a stormwater wetland

Consider the subsections 4.4.3.4 and 4.4.3.5-A (Location and Siting).

Step 3. Confirm design criteria and applicability

Check with the local jurisdiction, TDEC, or other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply to the site.

Step 4. Compute WQv peak discharge (Q_{wq})

The peak rate of discharge for the water quality design storm is needed for sizing the off-line diversion structures (see Chapter 3 for more information on this calculation).

(a) Using WQv, compute CN

(b) Compute time of concentration using TR-55 method

(c) Determine appropriate unit peak discharge from time of concentration

(d) Compute Q_{wq} in inches from unit peak discharge, drainage area, and WQv.

Step 5. Size flow diversion structure

A flow regulator should be supplied to divert the WQv to the submerged gravel wetland. Size low flow orifice, weir, or other device to pass Q_{wq}.

Step 6. Determine pretreatment volume

A sediment forebay is provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the gravel wetland. The forebay shall be sized to contain 0.1 inches per impervious acre (363 ft^3) of contributing drainage and shall be 4 to 6 feet deep. The forebay storage volume counts toward the total WQv requirement and may be subtracted from the WQv for subsequent calculations.

Step 7. Design inlets, sediment forebay(s), outlet structures, maintenance access, and safety features.

See subsection 4.4.3.5 for more details.

Step 8. Design landscape plan

A landscape plan for a stormwater wetland shall be prepared to indicate how it will be stabilized and established with vegetation. See subsection 4.4.3.5-E (Landscaping) for more details.

This page left intentionally blank

4.4.3.7 Inspection and Maintenance Requirements

Note: Section 4.4.3.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of a submerged gravel wetland as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local jurisdiction has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for submerged gravel wetlands, along with a suggested frequency for each activity. Individual gravel wetlands may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e.., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the gravel wetlands in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• Ensure that inlets and outlets to each submerged gravel wetland cell are free from debris and not clogged.	Monthly
• Check for sediment buildup in gravel bed.	Annually
Maintenance Activities	**Suggested Schedule**
• If sediment buildup is preventing flow through the wetland, remove gravel and sediment from cell. Replace with clean gravel and replant vegetation.	As needed
• Ensure that inlets and outlets to each submerged gravel wetland cell are free from debris and not clogged.	Monthly
• Check for sediment buildup in gravel bed.	Annually

Use of the inspection checklist that is presented on the next page is encouraged to guide the property owner in the inspection and maintenance of submerged gravel wetlands. The local jurisdiction can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the submerged gravel wetland. Questions regarding stormwater facility inspection and maintenance should be referred to the local jurisdiction.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
SUBMERGED GRAVEL WETLAND INSPECTION CHECKLIST

Location: ________________________________ Owner Change since last inspection? Y N
Owner Name, Address, Phone: ________________________________
Date: __________ Time: ____________ Site conditions:________________________________

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Wetland Area		
Healthy vegetation?		
Animal burrows present?		
Erosion in drainage area feeding wetland?		
Other (describe)?		
Inlet/Outlet Structures and Channels		
Clear of debris and functional?		
Trash rack clear of debris and functional?		
Sediment accumulation?		
Condition of concrete/masonry?		
Metal pipes in good condition?		
Control valve operation?		
Drain valve operation?		
Outfall channels function, not eroding?		
Other (describe)?		
Sediment Forebays		
Evidence of sediment accumulation?		
Wetland Vegetation Areas		
Vegetation adequate?		
Undesirable vegetation growth?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

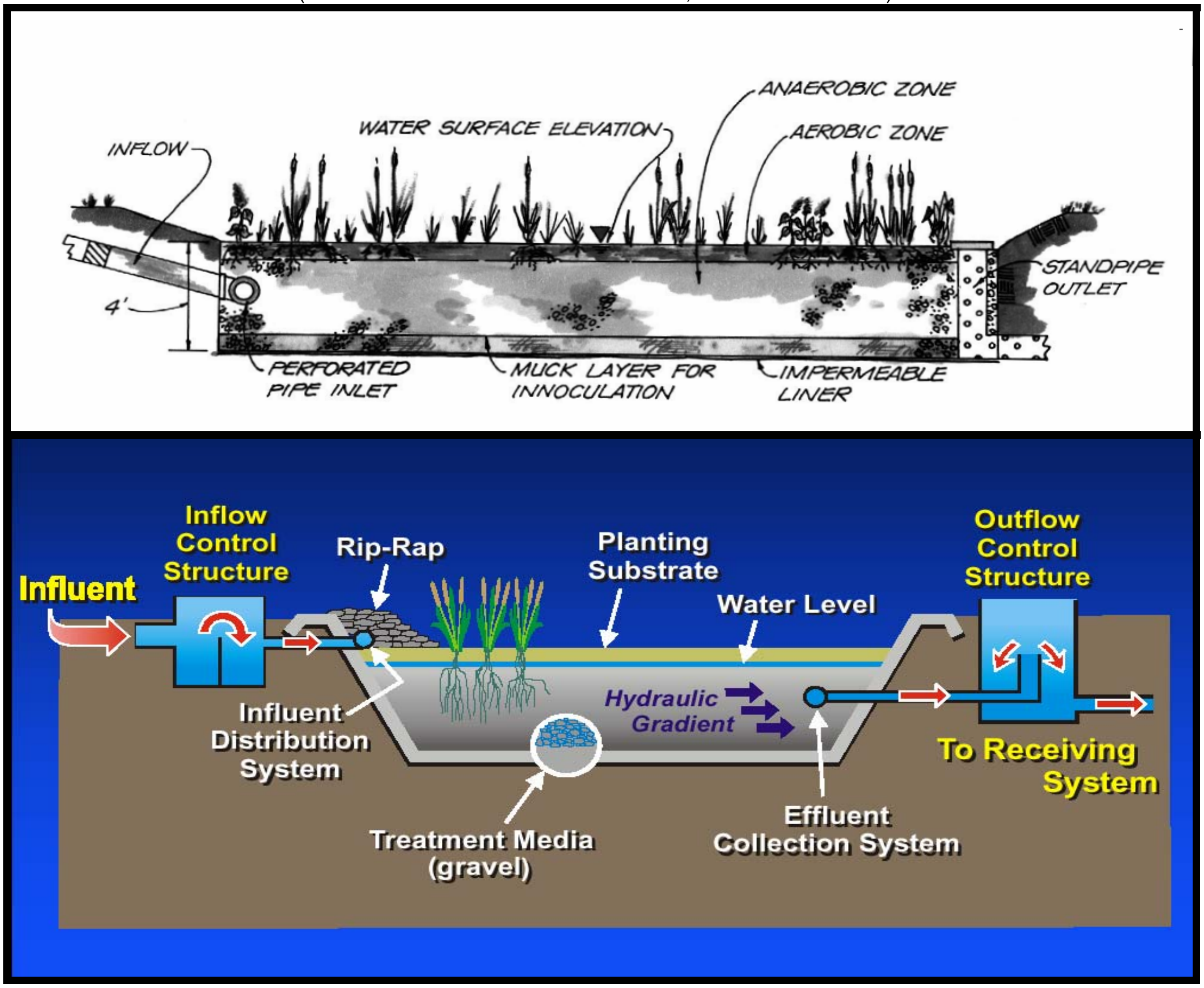
Corrective Action Needed	Due Date

Inspector Signature:______________________ Inspector Name (printed)______________________

4.4.3.8 Example Schematic

Figure 4-64. Schematic of a Submerged Gravel Wetland System

(Sources: Center for Watershed Protection; Roux Associates Inc.)



4.4.3.9 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

Center for Watershed Protection (CWP). *Design of Stormwater Filtering Systems.* Prepared for the Chesapeake Research Consortium, Solomons, MD, and U.S. EPA Region 5, Chicago, IL, by the Center for Watershed Protection, Ellicott City, MD, 1996.

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center, Accessed July 2005. *www.stormwatercenter.net*

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

Maryland Department of the Environment (MDE). *Maryland Stormwater Design Manual.* 2000. Available at: http://www.mde.state.md.us/programs/waterprograms/sedimentandstormwater/stormwater_design/index.asp.

New Jersey Department of Environmental Protection. *Stormwater Best Management Practices Manual.* 2004.

Northern Virginia Planning District Commission (NVPDC). Northern Virginia BMP Handbook. Annadale, Virginia: November 1992.

Schueler, T.R. Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region. Washington, D.C.: Metrolpolitan Washington Council of Governments (MWCOG), October, 1992.

4.4.3.10 Suggested Reading

Adams, L., Dove L.E., D.L. Leedy, and T. Franklin. *Urban Wetlands for Stormwater Control and Wildlife Enhancement – Analysis and Evaluation.* Urban Wildlife Research Center, Columbia, Maryland, 1983.

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

US EPA. *Storm Water Technology Fact Sheet: Storm Water Wetlands.* EPA 832-F-99-025, Office of Water, 1999.

Faulkner, S. and C. Richardson. *Physical and Chemical Characteristics of Freshwater Wetland Soils.* Constructed Wetlands for Wastewater Treatment, ed. D. Hammer, Lewis Publishers, 831 pp, 1991.

Guntenspergen, G.R., F. Stearns, and J. A. Kadlec. *Wetland Vegetation.* Constructed Wetlands for Wastewater Treatment, ed. D. A. Hammer, Lewis Publishers, 1991.

Metropolitan Washington Council of Governments (MWCOG). A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone. March, 1992.

4.4.4 Alum Treatment System

**Limited Application
Water Quality BMP**

Description: Alum treatment systems provide chemical treatment of stormwater runoff by means of adding liquid aluminum sulfate (alum) to sediment-laden runoff. The alum combines with suspended solids, phosphorus and heavy metals causing them to settle-out of suspension.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Intended for areas requiring regional stormwater treatment from a piped stormwater drainage system where general application BMPs are not feasible.
- Typical drainage area > 50 acres.
- Typically consists of mechanical/electrical dosing system, chemical storage facilities, a downstream settling pond and floc drying beds.

ADVANTAGES / BENEFITS:

- High pollutant removal capability.
- Can be used as a regional stormwater treatment BMP.

DISADVANTAGES / LIMITATIONS:

- High capital, operations and maintenance costs.
- Requires more frequent maintenance than most other stormwater treatment controls.
- Generally, not cost effective for small sites.
- Potential for stormwater quality impacts must be evaluated prior to design/use of the system.

MAINTENANCE REQUIREMENTS:

- Requires trained system operator.
- Restock chemicals frequently.
- Inspect and maintain all components on a frequent, routine basis.
- Remove floc build-up from settling pond.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**No**
Detention/Retention:	**No**

Accepts hotspot runoff: *No.*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**High**
Maintenance Burden:	**High**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**No**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**90%**

4.4.4.1 General Description

The process of alum (aluminum sulfate) treatment provides treatment of stormwater runoff from a piped stormwater drainage system entering a wet pond by injecting liquid alum into storm sewer lines on a flow-weighted basis during rain events. When added to runoff, liquid alum forms the harmless precipitates of aluminum hydroxide [$Al(OH)_3$] and aluminum phosphate [$AlPO_4$]. These precipitates combine with suspended solids, phosphorus and heavy metals, which then settle-out in a downstream capture pond.

An alum treatment system generally consists of three parts: a flow-weighted dosing system that fits inside a storm sewer manhole; remotely located alum storage tanks; and a downstream settling pond that allows the alum, pollutants and sediments to settle out. (Kurz, 1998). Disposal of the floc that settles in the downstream pond is critical, because of the concentration of dissolved chemicals, and also because bacteria and viruses remain viable in the floc layer (Kurz, 1998). In addition to the settling pond, a separate floc collection pump-out facility should be installed to further reduce the chance of resuspension and transport of floc to receiving waterbodies. The pump disposes the floc into the sanitary sewer system or onto nearby upland areas or sludge drying beds. Permits (from the local utility) will be required to pump to the sanitary sewer, however. The quantity of sludge produced at a site can be as much as 0.5 percent of the volume of water treated (Gibb et al., 1991). Figures 4-65 and 4-66 provide photographs of an alum treatment system settling pond and dosing/injection system, respectively.

Figure 4-65. Settling Basin for an Alum Treatment System
(Source: Georgia Stormwater Management Manual)

Figure 4-66. Dosing/Injection Components of an Alum Treatment System
(Source: Georgia Stormwater Management Manual)

The precipitate that is formed when alum is injected into the stormwater system is stable in sediments and will not re-dissolve due to changes in redox potential or pH under conditions normally found in surface water bodies. Laboratory or field testing may be necessary to verify feasibility and to establish design, maintenance, and operational parameters, such as the optimum coagulant dose required to achieve the desired water quality goals, chemical pumping rates and pump sizes.

Alum treatment systems can be expensive to construct and maintain. Capital construction costs depend primarily on the number of outfall locations treated rather than the size of the area draining to the system. Operations and maintenance expenses include costs for chemicals, power to the system, manpower for routine inspections and maintenance, and equipment renewal and replacement costs. In addition, regulatory agencies or wastewater utilities may require long-term monitoring of water quality downstream of alum treatment systems, which further increases maintenance costs.

4.4.4.2 Stormwater Management Suitability

Alum treatment systems are designed primarily for large watersheds. They are designed solely for the purpose of treating stormwater quality and do not have the ability to provide channel or flood protection.

4.4.4.3 Pollutant Removal Capabilities

The total suspended solids design pollutant removal rate of 90% is a conservative average pollutant reduction percentage for design purposes derived from sampling data, modeling and professional judgment.

For additional information and data on pollutant removal capabilities for alum treatment systems, see the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the International Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

4.4.4.4 Application and Site Feasibility Criteria

The following basic criteria should be evaluated to ensure the suitability of an alum treatment system for meeting stormwater management objectives on a site or development.

General Feasibility

- Well-suited for large drainage areas that discharge into a closed body of water (e.g., an existing lake or pond).
- Suitable for use in high density/ultra-urban areas.
- Suitable for use as a regional stormwater control.

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – Typically 50 acres minimum for an alum treatment system.

4.4.4.5 Planning and Design Guidance

Alum treatment systems are fairly complex, and design details are beyond the scope of this manual. Further information can be obtained from the Internet and by contacting engineers who have designed and implemented successful systems. The local jurisdiction shall have the authority to set the design conditions for alum treatment systems on a case-by-case basis.

The following information is provided as guidance for the design of alum treatment systems.

- Injection points should be 100 feet upstream of discharge points.
- Alum concentration is typically 10 μg/l.
- Alum treatment systems may need to control pH.
- For new basin design, the required size is approximately 1% of the drainage basin size, as opposed to 10 to 15% of the drainage basin area for a standard detention basin.
- No volume requirement is required when discharging into a closed body of water (e.g., an existing lake or pond).

4.4.4.6 Inspection and Maintenance Requirements

Note: Section 4.4.4.6 and the operation and maintenance document supplied by the alum system designer must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of an alum treatment system as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local jurisdiction has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for alum treatment systems, along with a suggested frequency for each activity. Individual alum treatment systems may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the alum treatment system in proper operating condition at all times. <u>Inspections and maintenance of the alum treatment system must be performed by a trained system operator.</u>

Inspection Activities	Suggested Schedule
• Dosing equipment – monitor dosage of alum and other chemicals. Also monitor the expected flows through the system. • Perform routine inspection of dosing equipment and pump-out facility to ensure that all equipment is in proper operating condition. • Inspect dosing equipment and storage facility for signs of leaks or spills. • Inspect chemical amounts and restock if needed. • Monitor pH and other parameters in the settling basin to determine potential negative impacts to receiving waters. • Inspect settling basin for signs of damage, impending failure, and poor water quality. • Inspect storage capacity of settling basin and floc drying beds (if used).	Monthly or more frequently
Maintenance Activities	**Suggested Schedule**
• Adjust the dosage of alum and other chemicals and possibly regulate flows through the basin to ensure proper dosage and delivery of runoff to the settling basin. • Perform maintenance and repair of pump equipment, chemical supplies and delivery system. • Dredge settling basin and properly dispose of accumulated floc.	As Needed

Use of the inspection checklist presented below for is encouraged for guidance in the inspection and maintenance of the alum treatment system. The local jurisdiction can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the treatment system. Owners of alum treatment systems are encouraged to provide additional inspection/maintenance items to ensure the long-term proper operation of the treatment system. Questions regarding inspection and maintenance should be referred to the local jurisdiction.

INSPECTION CHECKLIST FOR ALUM TREATMENT SYSTEMS

Location: ____ Owner Change since last inspection? Y N
Owner Name, Address, Phone: ____
Date: __________ Time: ____________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Dosing System		
Dispensing proper dose?		
Signs of leaks or spills?		
In proper operating condition?		
Chemical Storage Facility		
Signs of leaks or spills?		
Proper delivery of chemicals to dosing system?		
In proper operating condition?		
Settling Pond		
pH and water quality condition?		
Erosion on embankment?		
Animal burrows in embankment?		
Cracking, sliding, bulging of dam?		
Blocked or malfunctioning drains?		
Leaks or seeps on embankment?		
Obstructions of spillway(s)?		
Clear of debris and functional?		
Sediment/floc accumulation?		
Condition of concrete/masonry?		
Metal pipes in good condition?		
Control valve operation?		
Pond drain valve operation?		
Channels/spillways function, not eroding?		
Other (describe)?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:______________________________ Inspector Name (printed)__________________________

4.4.4.7 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

Gibb, A., B. Bennet, and A. Birkbeck. *Urban Runoff Quality and Treatment: A Comprehensive Review*. Prepared for the Vancouver Regional District, the Municipality of Surrey, British Columbia, Ministry of Transportation and Highways, and British Columbia Ministry of Advanced Education and Trainiing. Document No. 2-51-246(242), 1991.

Harper, H.H. and J.L. Kerr. *Design, Alum Treatment of Stormwater Runoff: The First Ten Years.* Environmental Research and Design, Orlando, Florida, 1996.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

Kurz, R. *Removal of Microbial Indicators from Stormwater Using Sand Filtration, Wet Detention, and Alum Treatment Best Management Practices.* Southwest Florida Water Management District, Brooksville, Florida, 1998.

www.stormwaterauthority.org/assets/alum%20injection.pdf

4.4.4.8 Suggested Reading

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center. *www.stormwatercenter.net*

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

US EPA. *Storm Water Technology Fact Sheet: Sand Filters.* EPA 832-F-99-007. Office of Water. 1999.

Walker, W. *Phosphorus Removal by Urban Runoff Detention Basins.* Lake and Reservoir Management, North American Society for Lake Management, 314, 1987.

This page left intentionally blank

4.4.5 Proprietary Structural BMPs

Limited Application Water Quality BMP

Description: Proprietary systems are defined as manufactured stormwater treatment systems that are available from commercial vendors.

REASONS FOR LIMITED USE

Depending on the proprietary system, there may be:

- Limited performance data
- Application constraints
- High maintenance requirements
- Higher costs than other structural control alternatives

KEY CONSIDERATIONS

- Independent performance data must be available to prove a demonstrated capability of meeting stormwater management goal(s)
- System or device must be appropriate for use in local conditions
- Installation and operations/maintenance requirements must be understood by all parties approving and using the system or device in question

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	✷
Channel Protection:	✷
Detention/Retention:	✷

LAND USE APPLICABILITY

Residential/Subdivision Use:	✷
High Density/Ultra Urban Use:	✷
Commercial/Industrial Use:	✷

POLLUTANT REMOVAL

Total Suspended Solids:	✷

✷ Depends on the specific proprietary structural control.

Note: Proprietary systems are not recommended. This subsection is being included in order to provide policies for approving the use of a proprietary system or practice.

4.4.5.1 General Description

There are many types of commercially-available proprietary stormwater structural controls for both water quality treatment and quantity control. These systems include:

- Hydrodynamic systems such as gravity and vortex separators
- Filtration systems
- Catch basin media inserts
- Chemical treatment systems
- Package treatment plants
- Prefabricated detention structures

Many proprietary systems are useful on small sites and space-limited areas where there is not enough land or room for other structural BMP alternatives. Proprietary systems can often be used in pretreatment applications in a treatment train. However, proprietary systems are often more costly than other alternatives and may have high maintenance requirements. Perhaps the largest difficulty in using a proprietary system is the lack of adequate independent performance data, particularly for use in local conditions. Below are general guidelines that should be followed before considering the use of a proprietary commercial system.

4.4.5.2 Guidelines for Using Proprietary Systems

In order for use as a limited application control, a proprietary system must have a demonstrated capability of meeting the stormwater management goals for which it is being intended. This means the system must provide:

(1) Independent third-party scientific verification of the ability of the proprietary system to meet water quality treatment objectives and/or to provide water quantity control (channel or flood protection);

(2) Proven record of longevity in the field; and,

(3) Proven ability to function in local conditions (e.g., climate, rainfall patterns, soil types, etc.).

For a propriety system to meet item (1) listed above, the following monitoring criteria should be met for supporting studies:

- At least 15 storm events must be sampled;
- The study must be independent or independently verified (i.e., may not be conducted by the vendor or designer without third-party verification);
- The study must be conducted in the field, as opposed to laboratory testing;
- Field monitoring must be conducted using standard protocols which require proportional sampling both upstream and downstream of the device;
- Concentrations reported in the study must be flow-weighted; and,
- The propriety system or device must have been in place for at least one year at the time of monitoring

Although local data is preferred, data from other regions can be accepted as long as the design accounts for the local conditions.

The local jurisdiction may submit a proprietary system to further scrutiny based on the performance of similar practices. A poor performance record or high failure rate is valid justification for not allowing the use of a proprietary system or device. Consult the local jurisdiction for more information regarding the use of proprietary structural stormwater controls.

4.4.6 Underground Detention

Limited Application Water Quality BMP

Description: Detention storage located in underground pipe systems or vaults designed to provide water quantity control through detention and/or extended detention of storm-water runoff.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Maximum drainage area = 25 acres.
- Access point for maintenance required.
- Used downstream of a water quality BMP.

ADVANTAGES / BENEFITS:

- To be used for space-limited applications only.
- Good for retrofitting small urbanized lots.
- Concrete vaults or pipe systems can be used.
- Longevity is high, with proper maintenance.

DISADVANTAGES / LIMITATIONS:

- Controls for stormwater quantity only – not intended to provide water quality treatment.
- Dissolved pollutants are not removed.
- Frequent maintenance required.

MAINTENANCE REQUIREMENTS:

- Remove debris from inlet and outlet structures.
- Monitor sediment accumulation.
- Clean out sediment and floatable debris using catch basin cleaning equipment (vacuum pumps).

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**No**
Channel Protection:	**Yes**
Detention/Retention:	**Yes**

Accepts hotspot runoff: *No.*

COST CONSIDERATIONS

Land Requirement:	**Med - High**
Capital Cost:	**Med - High**
Maintenance Burden:	**Med - High**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**No**
High Density/Ultra Urban Use:	**No**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**10**

4.4.6.1 General Description

Underground detention is typically utilized on sites where developable surface area is at a minimum. Underground detention facilities can be either box-shaped facilities constructed with reinforced concrete, facilities constructed with large diameter metal or plastic pipe or commercially-available proprietary underground systems. All methods serve as alternatives to surface dry detention for stormwater quantity control where there is not adequate land for a dry detention basin or multi-purpose detention area.

Underground detention can provide channel protection through extended detention of the channel protection volume and overbank flood control (and in some cases extreme flood) through normal detention. Basic storage design and routing methods are the same as for dry detention basins except that the bypass for high flows must be included in the design.

Due to the potential problems that local conditions present, the use of underground detention is prohibited unless other peak discharge control options are deemed physically infeasible.

4.4.6.2 Pollutant Removal Capabilities

Underground detention facilities are not capable of significant pollutant removal. Therefore, because underground detention is not intended for water quality treatment, it must be used in a treatment train approach with other structural BMPs that provide treatment of the WQv. This will prevent the underground pipe systems or vaults from becoming clogged with trash or sediment and significantly reducing the maintenance requirements.

4.4.6.3 Planning and Design Standards

If underground detention is allowed by the local municipality, the following standards shall be considered **minimum** design standards for the design of underground detention. Underground detention that is not designed to these standards will not be approved. The local municipality shall have the authority to require additional design conditions if deemed necessary.

<u>A. LOCATION AND SITING</u>

- The maximum contributing drainage area to be served by a single underground detention vault or tank is 25 acres.
- Flood protection controls should be designed as final controls for on-site stormwater. Therefore, underground detention will typically be located downstream of structural stormwater BMPs that are designed to provide treatment of the water quality volume (WQv) and channel protection volume (CPv).
- Underground detention shall be placed in an easement that is recorded with the deed and shown on the plan. The easement shall be located 15 feet from the outside limits of the underground detention structure. Minimum setback requirements for the easement shall be as follows unless otherwise specified by the local jurisdiction:
  - From a public water system well – TDEC specified distance per designated category
  - From a private well – 50 feet; if the well is down gradient from a land use that must obtain a Special Pollution Abatement Permit, then the minimum setback is 250 feet
  - From a septic system tank/leach field – 50 feet
- The easement shall be located 15 feet from the outside limits of the underground detention structure. The first floor elevation (FFE) for any structure adjacent to underground detention shall have an elevation no lower than 1 foot above the emergency spillway elevation.

<u>B. GENERAL DESIGN</u>

- Underground detention shall consist of the following elements, designed in accordance with the specifications provided in this section.

  (1) An outlet structure;

(2) An emergency bypass; and

(3) Maintenance access.

- Underground detention systems that are used to provide extended detention of the channel protection volume or water quality volume shall have watertight joints and piping.
- Routing calculations must be used to demonstrate that the storage volume is adequate. See Chapter 3 for procedures on the design of detention storage.
- Adequate maintenance access must be provided for all underground detention systems. Access must be provided over the inlet pipe and outflow structure. Access openings can consist of a standard frame, grate and solid cover, or a removable panel. Vaults with widths of 10 feet or less should have removable lids.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

- Underground detention vaults and tanks must meet structural requirements for overburden support and traffic loading if appropriate.
- Detention Vaults: Minimum 3,000 psi structural reinforced concrete may be used for underground detention vaults. All construction joints must be provided with water stops. Cast-in-place wall sections must be designed as retaining walls. The maximum depth from finished grade to the vault invert should be 20 feet.
- Detention Pipes: The minimum pipe diameter for underground detention is 36 inches.

D. INLET and OUTLET STRUCTURES

- A separate sediment sump or vault chamber sized to contain 0.1 inch per impervious acre (363 ft^3) of contributing drainage should be provided at the inlet for underground detention systems that do not receive pretreatment from water quality structural BMPs.
- For CPv control, a low flow orifice capable of releasing the channel protection volume over 24-72 hours may be provided if the CPv is not handled by another BMP. The channel protection orifice should be adequately protected from clogging by an acceptable external trash rack. Orifice diameters less than three inches may be used if internal orifice protection is used (i.e., an over perforated vertical stand pipe with 0.5-inch orifices or slots that are protected by wire cloth and a stone filtering jacket). Adjustable slide gates can also be used to achieve this equivalent diameter.
- Additional outlets are sized for peak flow control (based upon hydrologic routing calculations) and can consist of weirs, orifices, outlet pipes, combination outlets, or other acceptable control structures.
- Water shall not be discharged from underground detention in an erosive manner. Riprap, plunge pools or pads, or other energy dissipaters are to be placed at the end of the outlet to prevent scouring and erosion. If a pond outlet discharges immediately to a channel that carries dry weather flow, care should be taken to minimize disturbance along the downstream channel and streambanks, and to reestablish a forested riparian zone in the shortest possible distance (if the downstream area is located in a vegetated buffer).

E. EMERGENCY BYPASS

- A high flow bypass shall be included in the underground detention design to safely pass flows greater than the maximum storm used by the local jurisdiction or in the event of outlet structure blockage or mechanical failure. The bypass shall be located so that downstream structures will not be impacted by emergency discharges.

F. MAINTENANCE ACCESS

- A maintenance right-of-way or easement having a minimum width of 20 feet shall be provided from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.

- The maintenance access shall extend to the forebay (if included) and outlet works, and, to the extent feasible, be designed to allow vehicles to turn around.

4.4.6.4 Design Procedures

In general, site designers should perform the following design procedures when designing underground detention.

Step 1. Compute runoff control volumes.

Calculate WQv and CPv in accordance with the guidance presented in Chapter 3. Consult local regulations for peak discharge control (i.e., detention) requirements.

Step 2. Confirm design criteria and applicability.

Consider any special site-specific design conditions/criteria from subsection 4.4.6.3. Check with the local jurisdiction, TDEC, or other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply to the site.

Step 3. Calculate discharge release rates and water surface elevations.

Set up stage-storage-discharge relationships for the control structure for the local design storms.

Step 4. Design spillway(s)

Size emergency bypass and analyze safe passage of the maximum local design storm. Set the emergency bypass inlet elevation a minimum of 0.1 feet above the water surface elevation for the maximum local design storm.

Step 5. Design inlets, outlet structures and maintenance access.

See subsection 4.4.6.3 for more details.

4.4.6.5 Maintenance Requirements and Inspection Checklist

Note: Section 4.4.6.5 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of underground detention as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local municipality has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for underground detention, along with a suggested frequency for each activity. Individual underground detention locations may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the pond in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• After several storm events or an extreme storm event, inspect for: signs of clogging of the inlet or outlet structures and sediment accumulation.	As Needed
• Inspect for: trash and debris; clogging of the outlet structures and any pilot channels; excessive erosion; sediment accumulation in the basin and inlet/outlet structures; tree growth on dam or embankment; the presence of burrowing animals; standing water where there should be none; vigor and density of the grass turf on the basin side slopes and floor; differential settlement; cracking; leakage; and slope stability.	Semi-annually
• Inspect that the outlet structures, pipes, and downstream and pilot channels are free of debris and are operational. • Note signs of pollution, such as oil sheens, discolored water, or unpleasant odors. • Check for sediment accumulation in the facility. • Check for proper operation of control gates, valves or other mechanical devices.	Annually
Maintenance Activities	**Suggested Schedule**
• Perform structural repairs to inlet and outlets • Clean and remove debris from inlet and outlet structures.	Monthly or as needed
• Repair damage to inlet or outlet structures, control gates, valves, or other mechanical devices; repair undercut or eroded areas.	As Needed
• Monitor sediment accumulations, and remove sediment when the pond volume has become reduced significantly.	As Needed

Use of the inspection checklist that is presented on the next page is encouraged to guide the property owner in the inspection and maintenance of underground detention facilities. The local municipality can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the underground detention facilities. Questions regarding stormwater facility inspection and maintenance should be referred to the local jurisdiction.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
UNDERGROUND DETENTION INSPECTION CHECKLIST

Location: ______________________________ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ______________________________

Date: ___________ Time: _____________ Site conditions:______________________________

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Inlet/Outlet Structures		
Clear of debris and functional?		
Trash rack clear of debris and functional?		
Sediment accumulation?		
Condition of concrete/masonry?		
Metal pipes in good condition?		
Control valve operational?		
Pond drain valve operational?		
Outfall channels function, not eroding?		
Other (describe)?		
Pond Bottom		
Excessive sedimentation?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature: ______________________________ Inspector Name (printed)______________________________

4.4.6.6 Example Schematics

Figure 4-67. Example Underground Detention Pipe System

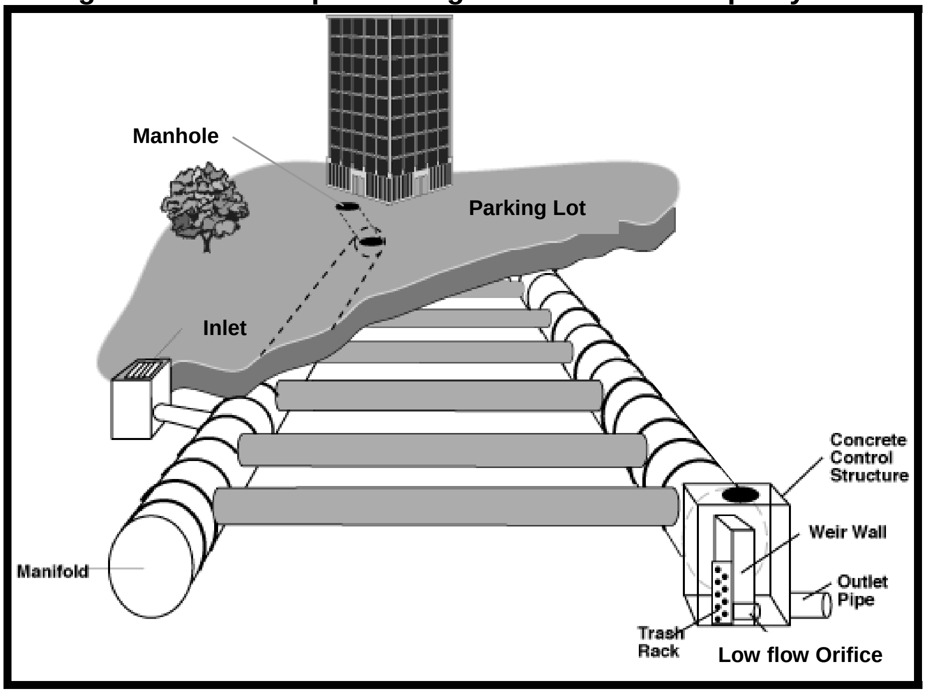
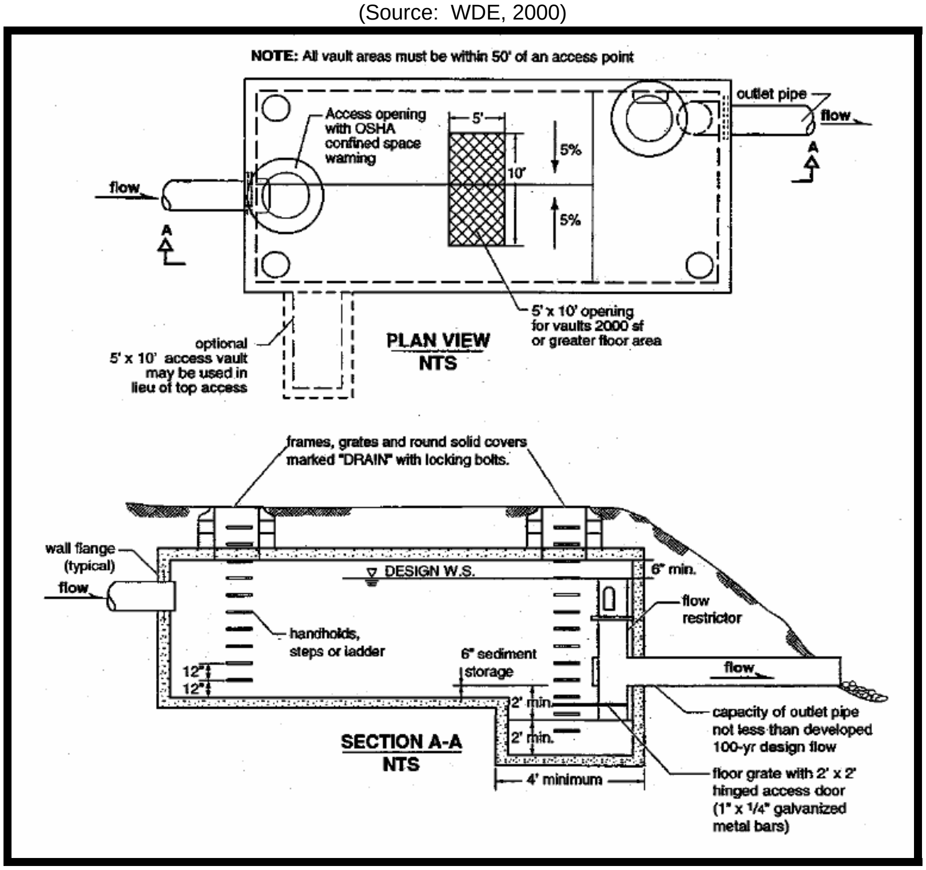


Figure 4-68. Schematic of a Typical Underground Detention Vault
(Source: WDE, 2000)



4.4.6.7 References

City of Nashville, Tennessee. *Metropolitan Nashville and Davidson County Stormwater Management Manual, Volume 4 Best Management Practices.* 2006.

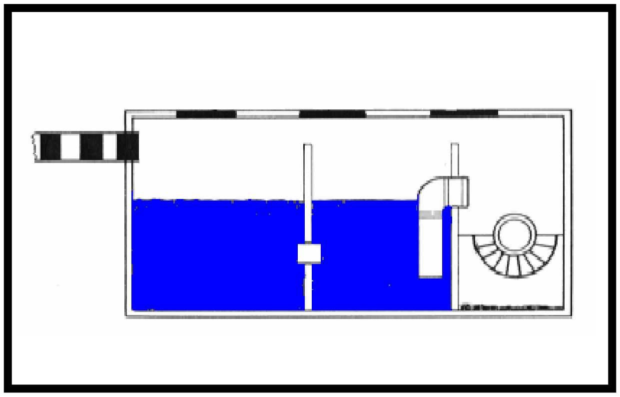
Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

Washington State Department of Ecology. *Stormwater Management Manual for Western Washington.* 2000.

4.4.7 Oil-Grit (Gravity) Separator

Limited Application Water Quality BMP



Description: The oil/grit separator is a device designed to remove settleable solids, oil and grease, debris and floatables from stormwater runoff. This is done through gravitational settling and trapping of pollutants. Oil-grit separators are also called gravity separators or oil/water separators.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Maximum drainage area of 1 acre.
- Access for maintenance is required.
- Performance dependent on design and frequency of inspection and cleanout of unit.
- Openings to device must be 1/16 inch or less to prevent mosquito intrusion and breeding.
- Install as an off-line device unless separator can be sized to handle a small drainage area.
- Install inspection/collection manhole on downstream side to provide easy access for sampling of effluent.

ADVANTAGES / BENEFITS:

- Good for sites where larger, or above-ground BMPs are not an option, or for retrofitting small urbanized lots.
- Can be used as pretreatment for other BMPs.
- Longevity is high, with proper maintenance.
- Standardized designs allow for easy installation.

DISADVANTAGES / LIMITATIONS:

- Cannot alone achieve the 80% TSS removal target.
- Limited performance data.
- Dissolved pollutants are not removed.
- Frequent maintenance required.

MAINTENANCE REQUIREMENTS:

- Inspect the gravity separator unit.
- Clean out sediment, oil and grease, and floatable debris using catch basin cleaning equipment (vacuum pumps).

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**No**
Detention/Retention:	**No**

Accepts hotspot runoff: *Yes, but two feet of separation distance required to water table when used in hotspot areas*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**Med - High**
Maintenance Burden:	**Med - High**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**No**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**No**

POLLUTANT REMOVAL

Total Suspended Solids:	**40%**

4.4.7.1 General Description

Oil-grit separators (also called oil/water separators or gravity separators) are hydrodynamic separation devices that are designed to remove grit and heavy sediments, oil and grease, debris and floatable matter (e.g., litter) from stormwater runoff through gravitational settling and trapping. There are two basic types of oil-grit separators, as displayed in Figure 4-71, in Section 4.4.7.8. Conventional separators rely upon gravity, physical characteristics of oil and sediments, and good design parameters to achieve pollutant removal. Coalescing plate interceptor (CPI) separators contain closely-spaced plates which greatly enhance the removal efficiency for oils and greases. In addition, a wide variety of separator systems are commercially-available in a variety of layouts, for which vendors have design data and procedures. Example schematics for both types of oil-water separators are displayed in Section 4.4.7.8.

Conventional oil-grit separator units contain a permanent pool of water and typically consist of an inlet chamber, separation/storage chamber, a bypass chamber, and an access port for maintenance purposes. Runoff enters the inlet chamber where heavy sediments and solids drop out. Then the flow moves into the main separation chamber, where further settling of suspended solids takes place. Oil and grease are skimmed and stored in a waste oil storage compartment for future removal. After moving into the outlet chamber, the clarified runoff is then discharged to the site's stormwater conveyance system. Oil-grit separators are sized based on the Water Quality Peak Flow Rate (Q_{wq}), which occurs during the water quality design storm. This contrasts with most other stormwater structural controls, which are sized based on capturing and treating a specific volume.

CPI separators include coalescing tubes or plates that provide an additional media in which minute oil globules can agglomerate to aid in the separation process. Oil that agglomerates around the coalescing tubes/plates can easily be skimmed through the gravity process. CPI separators must be utilized in "hotspot" areas where oil, grease, or other petroleum products are potential pollutants (e.g., fueling areas, gas stations, etc.).

The performance of oil-grit separator systems is based primarily on the relatively low solubility of petroleum products in water and the difference between the specific gravity of water and the specific gravities of petroleum compounds. Separators are not designed to separate other products such as solvents, detergents, or dissolved pollutants. The typical oil-grit separator unit may be enhanced with a pretreatment swirl concentrator chamber, oil draw-off devices that continuously remove the accumulated light liquids, and flow control valves that regulate the flow rate into the unit. Separators are available as prefabricated proprietary systems from a number of different commercial vendors. Some of the enhancements added by commercial vendors are presented in the example schematics presented in section 4.4.7.8.

4.4.7.2 Stormwater Management Suitability

Oil-grit separators are designed solely as stormwater quality treatment and do not have the ability to provide channel protection or flood protection. An important consideration when designing an oil-grit separator system for a site is how to bypass large storm events that exceed the design flow capacity around the separator without damaging the unit, exceeding the design flow capacity, or resuspending collected pollutants. Since resuspension of accumulated sediments and oil droplets is possible during heavy storm events, oil-grit separator units are typically installed off-line with a bypass installed to minimize pollutant wash-out or resuspension.

Water Quality (WQv)
To treat stormwater runoff, oil-grit separators rely on gravity and trapping to filter pollutants. An oil-grit separator cannot alone achieve the 80% TSS removal criteria. Therefore, separators are frequently used as the upstream pretreatment measure in a series of BMPs, ahead of a detention basin or constructed wetland.

4.4.7.3 Pollutant Removal Capabilities

Testing of gravity separators has shown that they can remove between 40% and 50% of the TSS loading when used in an off-line configuration (Curran, 1996 and Henry, 1999). Gravity separators also provide removal of debris, hydrocarbons, trash and other floatables. They provide only minimal removal of nutrients and organic matter.

The total suspended solids design pollutant removal rate of 40% is a conservative average pollutant reduction percentage for design purposes derived from sampling data, modeling and professional judgment

4.4.7.4 Application and Feasibility Criteria

One of the most important selection criteria when considering an oil-grit separator is the long-term maintenance and operation costs, and the need for regular inspections and cleanout. Inspection and maintenance needs for such systems can be considered high relative to other stormwater BMPs. Therefore, the oil-grit separator system should only be constructed if the property owner or tenant of the site has both the physical and fiscal ability to perform regular inspection and maintenance of the system on a long-term basis. This is one of the constraints that will be considered by the local municipality when oil-grit separators are proposed as a BMP for a development or redevelopment site.

Oil-grit separators are best used in commercial, industrial and transportation land uses and are intended primarily as a pretreatment measure for high-density or ultra-urban sites, or for use in hydrocarbon hotspots, such as gas stations and areas with high vehicular traffic. However, separators cannot be used for the removal of dissolved or emulsified oils or for pollutants such as coolants, soluble lubricants, glycols and alcohols. Suitable applications of an oil-grit separator include:

- pretreatment for other structural controls;
- parking lots, streets, driveways, truck loading areas;
- runways, marinas, loading wharves;
- gasoline stations, refueling areas;
- automotive repair facilities, oil-change businesses, fleet maintenance yards;
- recycling or salvage yards which accept automotive equipment; and,
- commercial vehicle washing facilities.

4.4.7.5 Planning and Design Standards

The design standards for oil-grit (gravity) separators are presented below. Design specifications developed by a commercial vendor for prefabricated proprietary systems can also be utilized, but must be approved where such specifications differ and/or are less stringent from the standards presented below. The local jurisdiction shall have the authority to require additional design conditions if deemed necessary.

<u>A. LOCATION AND SITING</u>

- Any individual oil-grit separator shall have a contributing drainage area no greater than 1 acre.
- It is desirable to maintain reasonable dimensions by bypassing larger storm flows in excess of the design flow rates. Thus, it is preferred that oil-grit separators be located off-line. An off-line separator can be an existing or proposed manhole with a baffle or other control (shown in Figure 4-71).
- Oil-grit separator systems can be installed in almost any soil or terrain. Since these devices are underground, appearance is not an issue and public safety risks are low.
- The design loading rate for oil-grit separators is low; therefore, they can only be cost-effectively sized to detain and treat the water quality volume, or other low flows if required by local municipalities. It is usually not economical or feasible to size an oil-grit separator to treat large design storms. Oil-grit separators require frequent maintenance for the life of the separator unit. Maintenance can be minimized (and performance can be increased) by careful planning and design, particularly upstream and downstream of the separator unit.

- Each oil-grit separator shall be placed in an easement that is recorded with the deed. The easement shall be defined at the outer edge of oil-grit separator. Minimum setback requirements for the easement shall be as follows unless otherwise specified by the local jurisdiction:
  - From a property line – 10 feet;
  - From a public water system well – TDEC specified distance per designated category;
  - From a private well – 100 feet; if well is downgradient from a land use that requires a Special Pollution Abatement Permit, then the minimum setback is 250 feet;
  - From a septic system tank/leach field – 50 feet.

B. PHYSICAL SPECIFICATIONS / GEOMETRY

- Design procedures for commercially available oil-grit separators are usually given by the manufacturer in simplified tables or graphs based on field testing and observed pollutant removal rates. Pollutant removal rates higher than those indicated in Section 4.4.7.3 must be proven using the criteria for proprietary BMPs presented in Section 4.4.5 of this manual.
- Oil-grit separators must be constructed with watertight joints and seals.
- The separation chamber shall provide for three separate storage volumes, as follows:
  (1) A volume for separated oil storage at the top of the chamber;
  (2) A volume for settleable solids accumulation at the bottom of the chamber; and,
  (3) A volume required to give adequate flow-through detention time for separation of oil and sediment from the stormwater flow.
- Ideally, a gravity separator design will provide an oil draw-off mechanism to a separate chamber or storage area. This design is required where a gravity separator is utilized to treat oil, grease and/or petroleum hotspots.
- Oil-grit separators are typically designed to bypass runoff flows in excess of the water quality volume peak flow. Some designs have built-in high flow bypass mechanisms, whereas others require a diversion structure or flow splitter located upstream of the device in the drainage system. Bypass mechanisms must minimize potential for captured pollutants from being washed-out or resuspended by large flows. Regardless of the bypass mechanism, an adequate outfall/outlet must be provided for both the discharge from the separator itself, and the bypassed discharge. Runoff shall be discharged in a non-erosive manner.
- The device shall be designed such that the velocity through the separation chamber does not exceed the entrance velocity.
- A trash rack shall be included in the design to capture floating debris, preferably near the inlet chamber to prevent debris from becoming oil impregnated.
- The total wet storage of the gravity separator unit shall be no less than 400 cubic feet per contributing impervious acre.
- The theoretical sizing of a conventional oil-grit separator requires the use of Stokes Law for the computation of rise velocity of oil droplets:

Equation 4.4.7.1

$$V_p = \frac{1.79 \times 10^{-8}(S_w - S_p){D_p}^2}{N}$$

where: V_p = upward rise velocity of petroleum droplet (ft/s)
S_w = specific gravity of water (0.998 to 1.000)
S_p = specific gravity of the petroleum droplet (typically 0.85 to 0.95)
D_p = diameter of petroleum droplet to be removed (microns)
N = absolute viscosity of water (poises)

The expected temperature is generally chosen for cold winter months. Typical values for the specific gravity and absolute viscosity of water at various temperatures are shown in the following table:

Temperature	S_w	N
32° F	0.999	0.01794
40° F	1.000	0.01546
50° F	0.999	0.01310
60° F	0.999	0.01129
70° F	0.998	0.00982

Sizing a Conventional Oil-Grit Separator:

- Using V_p above, a conventional oil-grit separator can be sized as follows:

Equation 4.4.7.2

$$D = \left(\frac{Q}{RV_H} \right)^{0.5}$$

Equation 4.4.7.3

$$W = RD$$

Equation 4.4.7.4

$$L = \frac{V_H D}{V_P}$$

Equation 4.4.7.5

$$V_H = \frac{V_P D}{L} = 15(V_P)$$

where: D = depth of unit (feet), generally between 3 and 8 feet
W = width of unit (feet), usually twice the depth
L = length of unit (feet), usually fifteen times the depth
Q = design flow rate (cfs), i.e., the water quality peak flow rate, Q_{wq}
R = width to depth ratio, generally a value of 2 is recommended
V_H = allowable horizontal velocity (ft/s), maximum 0.05 ft/s
V_p = upward rise velocity of oil droplet (ft/s)

- The total depth shall be adjusted by adding 1 foot of freeboard to the depth calculated using the equations above, or equations provided by a manufacturer.
- Top baffles should extend downward by 0.85D, and bottom baffles should extend upward by 0.15D, where D is the depth of the unit (in feet). The distribution baffle should be located at a distance of 0.10L from the inlet of the unit, where L is the length of the unit (in feet).

Sizing a Coalescing Plate Interceptor (CPI) Separator:

- CPI separators require considerably less space than a conventional separator to obtain the same effluent quality. A CPI separator is able to process smaller oil droplets by collecting them upon polyurethane plates or other materials. It is recommended that the design engineer consult vendors for a plate package that will meet site and flow criteria. Manufacturers will typically identify the capacity of various standard units.
- Using V_p above, a CPI separator can be sized as follows:

Equation 4.4.7.6

$$A_P = \frac{Q}{EV_P \cos(H)}$$

where: A_p = total surface area of coalescing plates (square ft)
Q = design flow rate (cfs), i.e., the water quality peak flow rate, Q_{wq}
E = efficiency of coalescent plates (typically 0.35 to 0.95)
V_p = upward rise velocity of oil droplet (ft/s)
H = angle of coalescing plates measured from horizontal (degrees), from 0° to 60°

- A plate angle of 45° to 60° is optimal, allowing sediment to slide off the plate and settle at the bottom of the chamber. At an angle of 0°, the plates would be horizontal and sediment will settle on the plates, reducing its effectiveness.
- Select a likely plate length and width, and then compute the number of plates needed using the following equation.

Equation 4.4.7.7

$$N = \frac{A_P}{W_P L_P}$$

where: N = number of plates required
A_p = total surface area of coalescing plates (ft^2)
W_p = width of plates (ft)
L_p = length of plates (ft)

- The space between the plates is usually about 1-inch. Placing plates closer together reduces the total required volume, but may instead allow debris such as twigs, plastics or paper to clog the plates.
- Calculate the chamber geometry and volume to contain the coalescing plates. Add a minimum of 1 foot below the plates to account for sediment storage. Add 6 to 12-inches above the plates for oil accumulation. Finally, add 1 foot above the oil accumulation allowance for freeboard.
- The CPI separator shall include a forebay chamber to collect floatable debris and evenly distribute flow if more than one plate is needed. Larger units may have a device to remove and store oil from the water surface, such as a skimmer or vacuum.

Manufactured (i.e., Proprietary) Oil-Grit Separators:

- Several manufacturers of oil-grit separators are identified in the references for this section. Manufactured separators should be selected on the basis of good design, suitability for the desired pollution control goals, durabilty, ease of installation, ease of maintenance, and reliability. The products listed in the reference section and/or shown in schematics are not the only products available, nor should their presence in this manual be construed as an endorsement of these products. They are merely shown as manufactured separators that are known to operate in Tennessee.
- Manufacturers generally provide design methods, installation guidelines, and proof of effectiveness for each application where used. These structures tend to include innovative methods of providing high flow bypass. However, it is incumbent upon the landowner to carefully investigate the suitability and overall trustworthiness of each manufacturer and/or subcontractor.

C. MAINTENANCE ACCESS

- A minimum 20 foot wide maintenance right-of-way easement shall be provided for the oil-grit separator from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles. The right-of-way shall be located such that maintenance vehicles and equipment can access the oil-grit separator.

4.4.7.6 Design Example

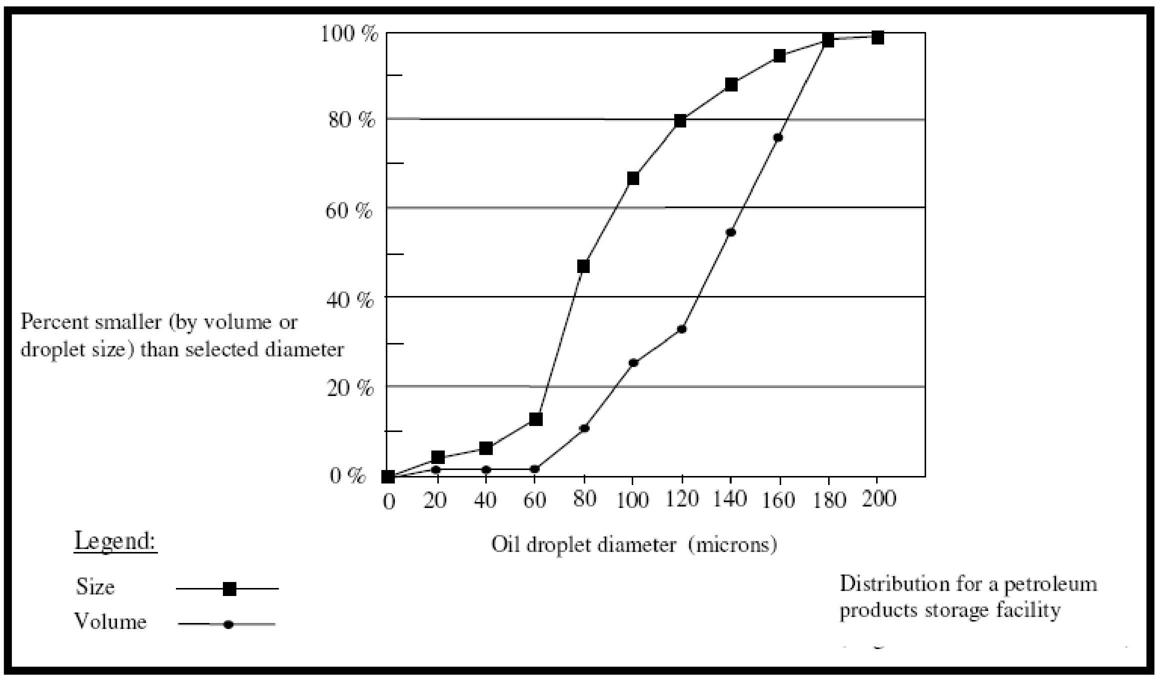
Basic Data

A conventional oil-grit separator unit is desired for use on a 1 acre parking lot.

- S_p = specific gravity of the petroleum droplet = 0.90
- V_p = 0.00080 ft/s for water temperature of 32°F (1 foot in 21 minutes)
- V_p = 0.00127 ft/s for water temperature of 60°F (1 foot in 13 minutes)
- Impervious percentage (I) = 90%
- Area (A) = 1 acre
- Time of concentration (t_c) = 6 minutes

Consider the effluent goal as 10 parts per million (ppm) and the design influent concentration is estimated to be 50 ppm (or equivalent to 50 mg/l), so that an oil removal efficiency of 80% is the desired target. From Figure 4-69 below, this can be achieved by removing all oil droplets with diameters of 90 microns or larger.

Figure 4-69. Typical Size and Volume Distribution of Oil Droplets
(Source: City of Knoxville, 2003)



Step 1: Calculate the Water Quality Peak Flow Rate (Q_{wq}):

(See Chapter 3 for equation information)

Compute the Runoff Peak Volume (Q_{wv}) in inches for 1.04-inch rainfall (P = 1.04):

$$Q_{wv} = PRv = 1.04Rv = 1.04(0.015 + (0.0092)(90)) = 0.93 \text{ inches}$$

Compute modified CN:

$$CN = 1000/[10+5P+10 Q_{wv} - 10(Q_{wv}^{2}+1.25Q_{wv}P)^{½}]$$
$$= 1000/[10+5(1.1)+10(0.93)-10(0.93^{2}+1.25(0.93)1.1)^{½}]$$
$$= 98.4 \quad \text{(Use CN = 98)}$$

For CN = 98 and an estimated time of concentration (t_c) of 6 minutes (0.1 hours), compute the Q_{wq} for a 1.1 inch storm.

I_a = 0.041 (from Table 3-13 in Chapter 3), therefore $I_a/P = 0.041/1.1 = 0.037$.

Using Figure 3-6 in Chapter 3, q_u can be estimated for a Type II storm as approximately 1000 csm/in or more (use 1000 csm/in because of limits in Figure 3-6).

q_u = 1000 csm/in, and therefore:

$Q_{wq} = q_u A\ Q_{wv}$ = (1000 csm/in) (1.0ac/640ac/mi2) (0.93in) = 1.45 cfs

Step 2: Size the oil-grit separator:

The allowable horizontal velocity (V_H) is:

$V_H = 15V_p = 15(0.00080) = 0.012$ ft/s

Compute the required depth (D), width (W) and length (L) of the unit (R = 2):

$D = (Q_{wq}/RV_H)^{0.5} = (1.45/(2)(0.012))^{0.5} = 7.8$ ft
$W = RD = 2(7.8) = 14.8$ ft
$L = (V_H D)/V_p = (0.012 \times 7.8)/0.00080 = 117$ ft

The very large size separator size (8' x 16' x 111') computed above is an indication of the fact that oil and water do not separate easily. By careful design of upstream and downstream reaches, it is possible to reduce turbulent flows, drop heights, mixing or swirling stormwater runoff, and excessive velocities. The large unit sized above also indicates the importance of subbasin size to unit size. It is important to keep drainage areas small (i.e., less than 1 acre); this will keep oil-grit separators to manageable sizes.

4.4.7.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.4.7.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective use of oil-grit (gravity) separators as stormwater best management practices. It is the responsibility of the property owner to maintain all stormwater facilities in accordance with the minimum design standards and other guidance provided in this manual. The local municipality has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for oil-grit (gravity) separators, along with a suggested frequency for each activity. Individual gravity separators may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain oil-grit separators properly at all times.

Inspection Activities	Suggested Schedule
• Inspect the gravity separator unit for clogging, accumulated debris, sediment, and/or oil and grease.	Regularly (at least every three months)
Maintenance Activities	**Suggested Schedule**
• 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 and included in the Operations and Maintenance Plan for the site.
- Consider using a licensed commercial subcontractor, who may have special equipment and abilities to perform periodic cleanout on oil-grit separators.
- Cleanout may require the implementation of confined-space procedures and equipment as required by OSHA regulations, such as non-sparking electrical equipment, oxygen meter, flammable gas meter, etc.
- Proper disposal of oil, solids and floatables removed from the gravity separator must be ensured. Floating oil, grease and petroleum substances removed using special vacuum hoses; should be treated as hazardous waste. Sediments may also contain heavy metals or other toxic substances and should be handled as hazardous waste.
- Removal of sediment depends upon accumulation rate, available storage, watershed size, nearby construction, industrial or commercial activities upstream, etc. The sediment composition should be identified by testing prior to disposal. Some sediment may contain contaminants for which the Tennessee Department of Environment and Conservation (TDEC) requires special disposal procedures. Consult TDEC's Division of Water Pollution Control if uncertain about what the sediments contain or if it is known to contain contaminants. Generally, give special attention or sampling to sediments accumulated in industrial or manufacturing facilities, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants are suspected to accumulate.
- There is usually uncertainty about what types of oil or petroleum products may be encountered. A significant percentage of petroleum products are attached to fine suspended solids, and therefore, are not easily removed by settling.
- The local municipality encourages the use of the inspection checklist presented below for guidance in the inspection and maintenance of the oil-grit separator. Additional items should be added to the list, based on the inspection and maintenance information provided by the manufacturer of the separator unit. The local municipality can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the unit. Questions regarding inspection and maintenance should be referred to the local municipality.

INSPECTION CHECKLIST: OIL-GRIT (OIL/WATER OR GRAVITY) SEPARATOR

Location: ____ Owner Change since last inspection? Y N
Type of Separator Unit (provide Manufacturer and Unit Name/ID if known): ______________________________
Owner Name, Address, Phone: ____
Date: __________ Time: ____________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Signs of clogging?		
Debris (trash) accumulation?		
Oil accumulation?		
Sediment accumulation?		
Standing water upstream of unit?		
Erosion downstream of unit?		
Other (describe)?		
Other (describe)?		
Other (describe)?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

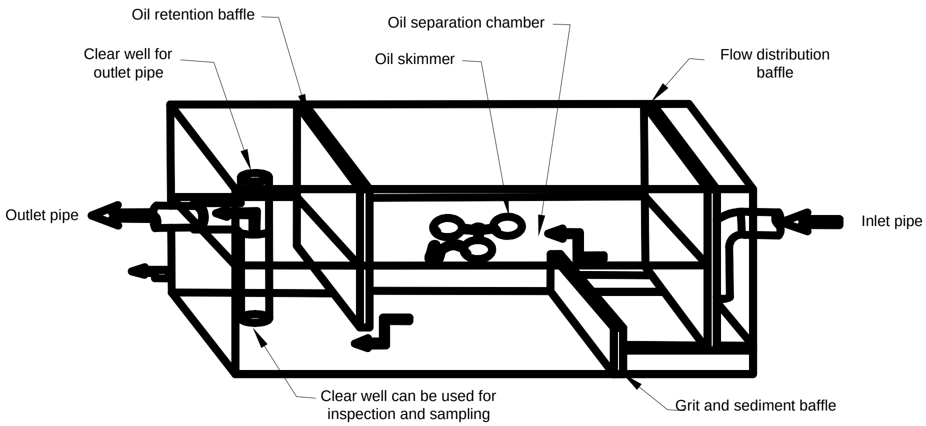
If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

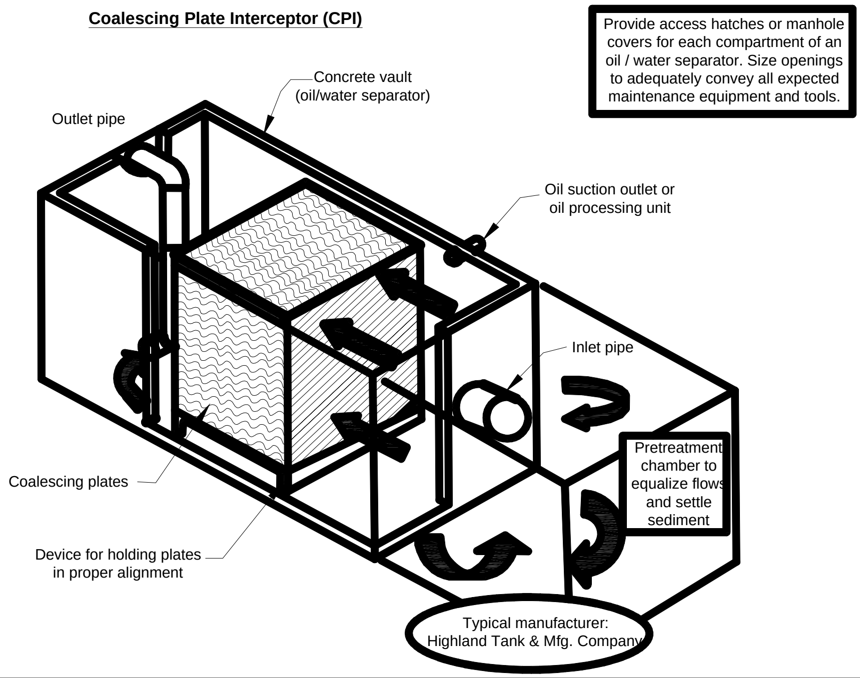
Corrective Action Needed	Due Date

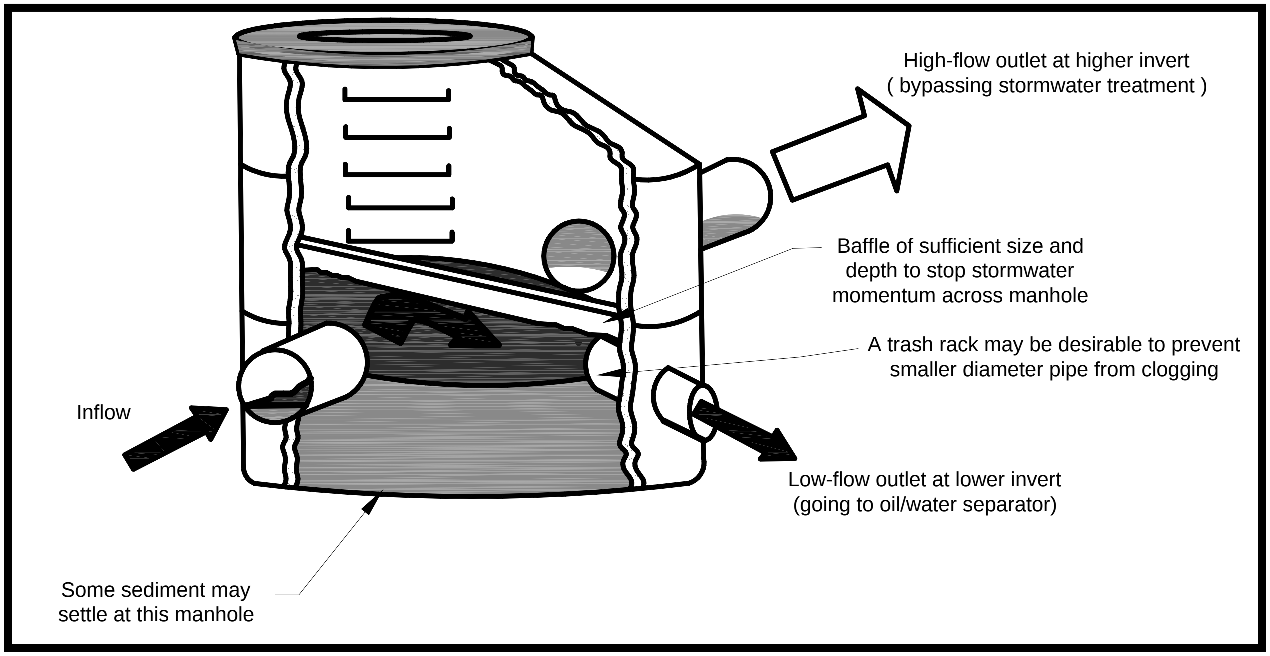
Inspector Signature:______________________________ Inspector Name (printed)______________________________

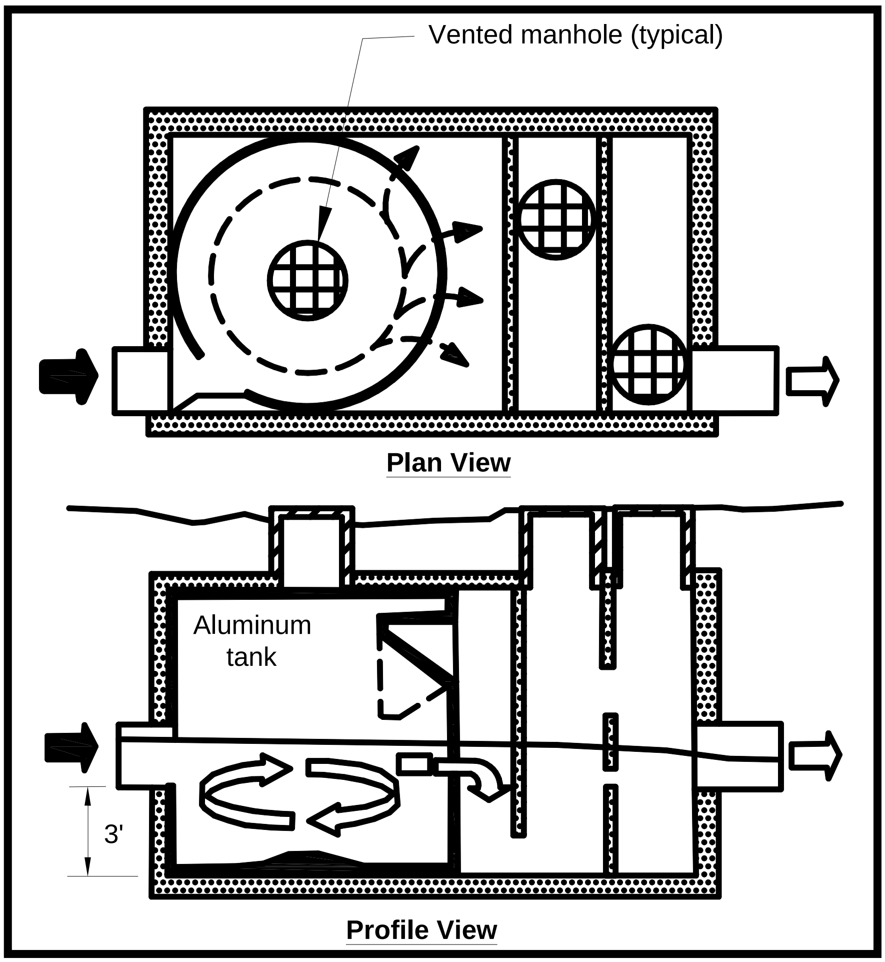
4.4.7.8 Example Schematics

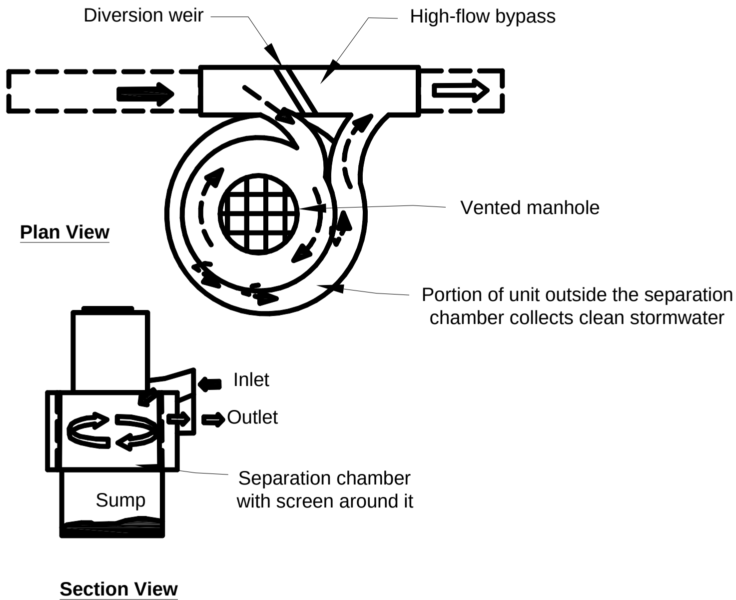
Figure 4-70. Typical Oil-Grit (Oil/Water) Separators
(City of Knoxville, 2003)





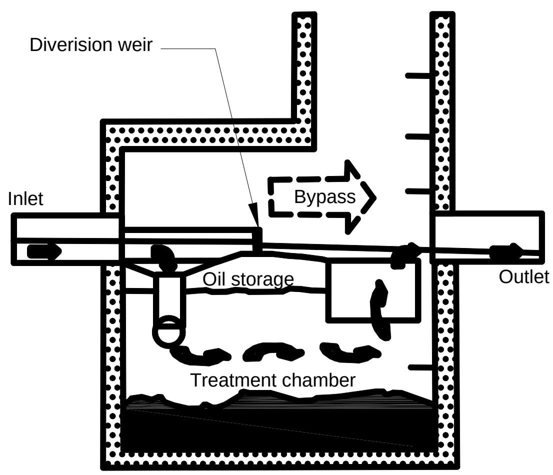

High-flow outlet at higher invert
(bypassing stormwater treatment)
Baffle of sufficient size and depth to stop stormwater momentum across manhole
A trash rack may be desirable to prevent smaller diameter pipe from clogging
Inflow
Low-flow outlet at lower invert
(going to oil/water separator)
Some sediment may settle at this manhole


Vented manhole (typical)
Plan View
Aluminum tank
3'
Profile View



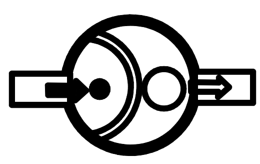
Notes:

1. This figure represents the continuous deflection stormwater treatment as manufactured by CDS Technologies. Units can also be retrofitted onto existing storm drains.
2. Units are manufactured from either fiberglass or precast concrete.
3. Manufacturer recommends the use of sorbent material within CDS separtion chamber to improve capture of oil and grease. Usage rate is typically several pounds of sorbent per acre per year.

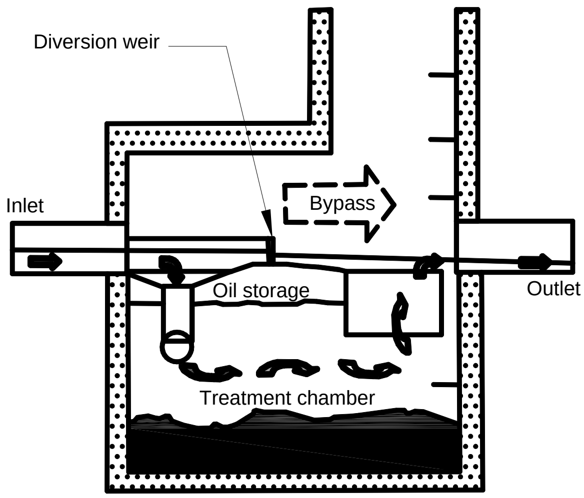


Notes:

1. This figure represents a single-unit system designed to process stormwater runoff on -line ,as manufactured by Stormceptor Corporation.
2. Unit consists of an insert placed into a standard concrete manhole. Basic size is 72" diameter, with larger sections used for the treatment chambers as needed.



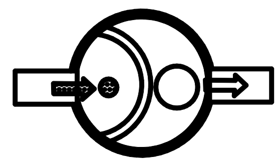
Plan view



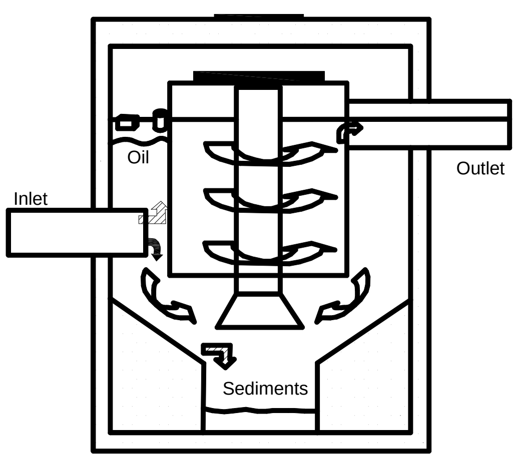
Notes:

1. This figure represents a single-unit system designed to process stormwater runoff on -line, as manufactured by Stormceptor Corporation.

2. Unit consists of an insert placed into a standard concrete manhole. Basic size is 72" diameter, with larger sections used for the treatment chambers as needed.



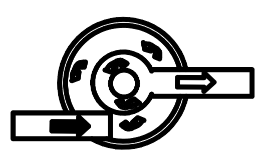
Plan view



Notes:

1. This figure shows a single unit to treat stormwater runoff, manufactured by H.I.L Technologies, Inc.

2. Unit consists of polyethylene components supported by a stainless frame, inserted into a standard concrete manhole. Concrete manhole sizes vary from 4' to 10'.



Plan view

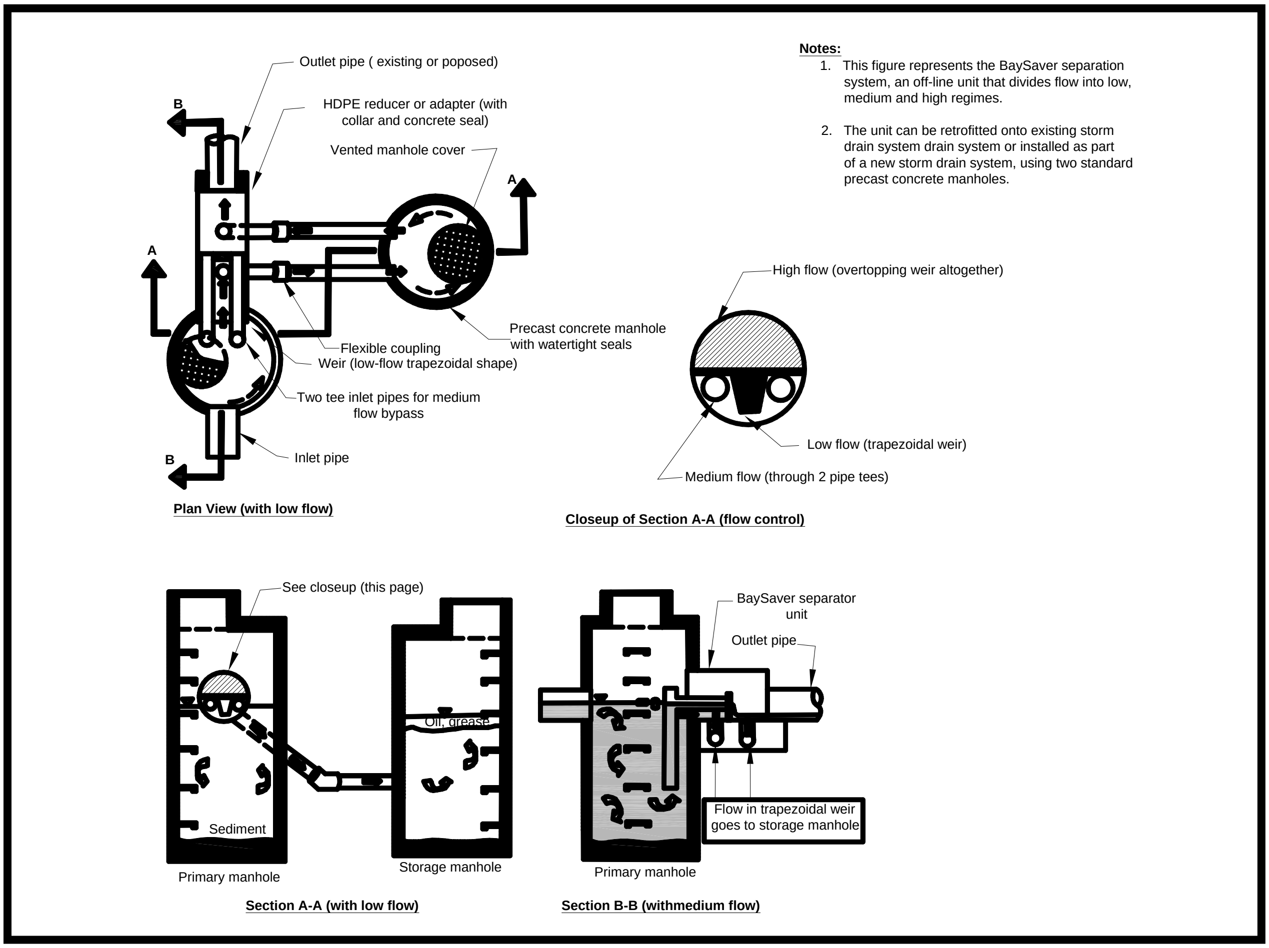
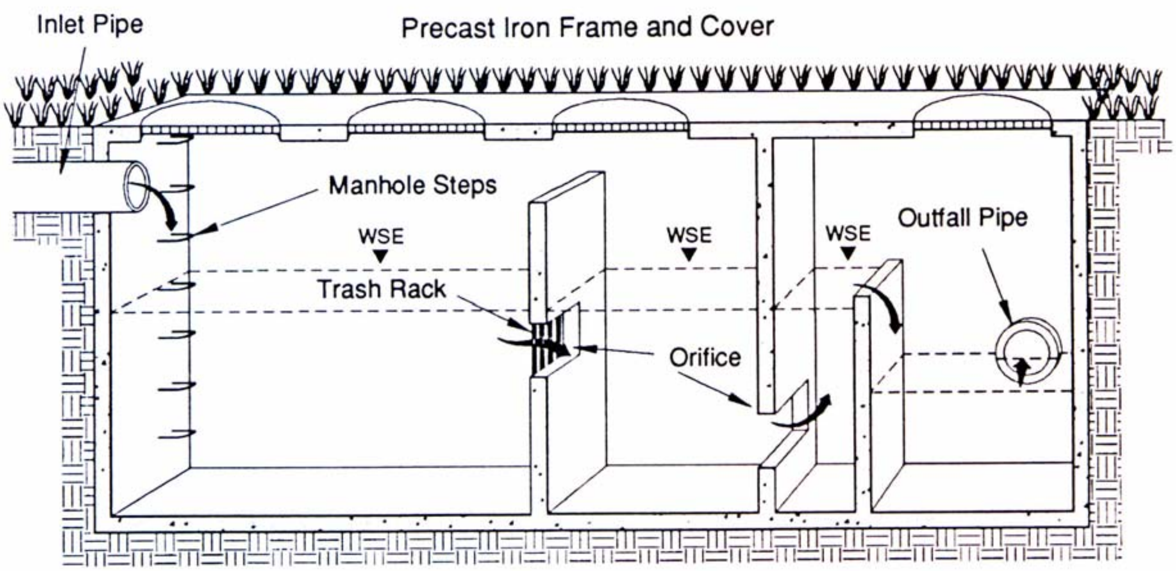

Notes:
1. This figure represents the BaySaver separation system, an off-line unit that divides flow into low, medium and high regimes.
2. The unit can be retrofitted onto existing storm drain system or installed as part of a new storm drain system, using two standard precast concrete manholes.
Outlet pipe (existing or poposed)
HDPE reducer or adapter (with collar and concrete seal)
Vented manhole cover
B
A
A
Flexible coupling
Weir (low-flow trapezoidal shape)
Precast concrete manhole with watertight seals
Two tee inlet pipes for medium flow bypass
Inlet pipe
B
Plan View (with low flow)
High flow (overtopping weir altogether)
Low flow (trapezoidal weir)
Medium flow (through 2 pipe tees)
Closeup of Section A-A (flow control)
See closeup (this page)
Oil, grease
Sediment
Primary manhole
Storage manhole
Section A-A (with low flow)
BaySaver separator unit
Outlet pipe
Flow in trapezoidal weir goes to storage manhole
Primary manhole
Section B-B (withmedium flow)

Figure 4-71. Schematic of an Example Gravity (Oil-Grit) Separator
(Source: NVRC, 1992)



4.4.7.9 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

City of Knoxville. *Knoxville Best Management Practices Manual.* City of Knoxville Stormwater Engineering Division, March 2003.

City of Nashville, Tennessee. *Metropolitan Nashville and Davidson County Stormwater Management Manual, Volume 4 Best Management Practices.* 2006.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*. 2006.

Metropolitan Council. *Minnesota Urban Small Sites BMP Manual.* Metropolitan Council Services, St. Paul Minnesota, 2001.

4.4.7.10 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks,* 1993.

4.4.7.11 Oil/Grit Separator Manufacturers

Highland Tank (CPI unit)	www.highlandtank.com
Vortechnics, Inc.	www.vortechnics.com
CDS Technologies	www.cdstech.com.au/us/
Stormceptor Corporation	www.stormceptor.com
H.I.L. Technology, Inc.	www.hil-tech.com
BaySaver, Inc.	www.baysaver.com
Aquashield, Inc.	www.squashieldinc.com
Environment 21, LLC	www.env21.com

This page left intentionally blank

Table of Contents

CHAPTER 5 — BETTER SITE DESIGN METHODS (WQv Reductions)

Chapter 5 - List of Figures

Chapter 5 - List of Tables

Chapter 5 - List of Examples

This page left intentionally blank

CHAPTER

5

BETTER SITE DESIGN METHODS (WQv Reductions)

5.1 Introduction

Stormwater management begins with the site planning and design process. Development projects can be designed to reduce their impact on watersheds when careful efforts are made to preserve natural areas, reduce impervious cover and better integrate stormwater treatment throughout the proposed development. By implementing a combination of these nonstructural approaches, collectively known as stormwater "better site design" practices, it is possible to reduce the amount of runoff and pollutants that are generated from a site and provide for some nonstructural on-site treatment and control of runoff.

The goals of better site design practices include:

- Managing stormwater (quantity and quality) runoff as close to the point of origin as possible, minimizing the need for large-scale collection and conveyance;
- Preventing stormwater impacts rather than mitigating them;
- Utilizing simple, nonstructural methods for stormwater management that are lower cost and lower maintenance than structural controls;
- Creating a multifunctional landscape; and
- Using hydrology as a framework for site design.

Better site design for stormwater management includes a number of site design techniques that lay-out the natural and proposed man-made site elements in a way that reduces the stormwater impact. This is achieved primarily by reducing the amount of impervious surfaces and utilizing natural features on the site for stormwater management. The aim is to reduce the environmental impact "footprint" of the site while retaining and enhancing the owner/developer's purpose and vision for the site. Many of the better site design concepts can reduce the cost of infrastructure while maintaining, and in some cases increasing, the value of the property.

Reduction of adverse stormwater runoff impacts through the use of better site design should be the **first** consideration of the design engineer. Operationally, economically, and aesthetically, the use of better site design practices offers significant benefits over treating and controlling runoff downstream. Therefore, it is often advantageous to explore and exhaust all options for better site design before considering structural stormwater controls.

The reduction in runoff and pollutants using better site design techniques can reduce peak discharges and runoff volume that need to be conveyed and controlled on a site and, therefore, the size and cost of necessary drainage infrastructure and structural stormwater controls. In some cases, the use of better site design practices may eliminate the need for structural controls entirely. Hence, better site design concepts can be viewed as both a water quantity and water quality management tool. The use of stormwater better site design can also have a number of other ancillary benefits including:

- Reduced construction costs;
- Increased property values;
- More open space for recreation;
- More pedestrian-friendly neighborhoods;
- Protection of sensitive forests, wetlands and habitats;
- More aesthetically pleasing and naturally attractive landscape; and,
- Easier compliance with wetland and other resource protection regulations.

Several of the site design practices described in this section provide a calculable reduction in the volume of water required for treatment. Section 5.2 discusses each reduction in detail, provides the reduction criteria and calculation rules, and presents examples of their application. A more general discussion of better site design practices is presented in Section 5.3.

5.2 Water Quality Volume (WQv) Reductions

5.2.1 Introduction

Nonstructural stormwater control practices are increasingly recognized as a critical feature in every site design. As such, a set of water quality volume "reductions" has been developed to provide developers and site designers an incentive to implement better site design practices that can reduce the volume of stormwater runoff and minimize the pollutant loads from a site. The reduction system directly translates into cost savings to the developer by reducing the size of structural stormwater control and conveyance facilities.

The basic premise of the reduction system is to recognize the water quality benefits of certain site design practices by allowing for a reduced water quality treatment volume (WQv). If a developer incorporates one or more of the reduction practices in the design of the site, the requirement for capture and treatment of the WQv will be decreased. Site designers are encouraged to utilize as many reductions as they can on a site. Greater decreases in stormwater storage volumes can be achieved when many reductions are combined (e.g., disconnecting rooftops and protecting natural conservation areas).

5.2.2 Site Planning Using WQv Reductions

During the site planning process, there are several steps involved in site layout and design, each more clearly defining the location and function of the various components of the stormwater management system. WQv reductions can be integrated with this process, as generally shown in Table 5-1.

Table 5-1. Integration of Site Design Reductions with Site Development Process

Site Development Phase	Site Design Reduction Activity
Initial Site Reconnaissance	• Identify and delineate natural features and potential preservation areas (natural areas, stream buffers, steep slopes, wetlands, springs and sinkholes, etc.). • Identify potential areas for better site design and WQv reductions.

Site Development Phase	Site Design Reduction Activity
Concept Plan	• Reduce impervious surface area through various better site design techniques. ✓ Preserve natural areas, stream buffers, steep slopes, wetlands, springs, sinkholes and other sensitive areas during site layout. ✓ Identify locations for use of vegetated channels. ✓ Look for areas to disconnect impervious surfaces. • Document the use of any WQv reductions.
Design Plan	• Perform layout and design of reduction areas – integrating them into treatment trains. • Ensure that WQv and channel protection volume (CPv) are satisfied. • Ensure appropriate documentation of WQv reductions in accordance with reduction criteria specified in this manual. • Develop maintenance requirements and documents for water quality management facilities and reduced areas.
Construction	• Ensure proper protection of preservation areas and buffers. • Ensure correct final construction of areas required to achieve reductions.
Final Inspection	• Prepare and submit Record Drawings, which will include reduction areas as appropriate. • Make any necessary corrections to easements on final plats. • Ensure reduction areas are identified on final plan and plat if applicable.

5.2.3 General Policies for WQv Reductions

The WQv reductions that are available in the local jurisdictions are listed in Table 5-2, and discussed in detail in the following sections.

Table 5-2. Summary of WQv Reductions

Reduction	Description
Reduction 1: Natural area preservation	Undisturbed natural areas are conserved on a site, thereby retaining their pre-development hydrologic and water quality characteristics.
Reduction 2: Managed area preservation	Managed areas of open space are preserved on a site, reducing total site runoff and retaining near pre-development hydrologic and water quality characteristics. *Note: This reduction is not available in every jurisdiction. See Appendices pertaining to policies for local jurisdictions.*
Reduction 3: Stream and vegetated buffers	Stormwater runoff is treated by directing sheet flow runoff through a naturally vegetated or forested buffer as overland flow.
Reduction 4: Vegetated channels	Vegetated channels are used to provide stormwater treatment.
Reduction 5: Impervious area disconnection	Overland flow filtration/infiltration zones are incorporated into the site design to receive runoff from rooftops and other small impervious areas.

Reduction	Description
Reduction 6: Environmentally sensitive large lot neighborhood	A group of site design techniques are applied to low and very low density residential development.

General requirements and policies applicable to all the WQv reductions are as follows.

1. WQv reductions can only be claimed if the area or practice for which reduction is requested conforms to all of the required minimum criteria and conditions stated in Section 5.2 of this manual. Reductions will not be given to areas or practices that do not conform to such criteria and conditions. The intent of this policy is to avoid situations that could lead to a reduction being granted without the corresponding decrease in pollution attributable to an effective better site design practice.
2. WQv reductions cannot be claimed twice for an identical area of the site (e.g. claiming a reduction for stream buffers and disconnecting rooftops over the same site area).
3. General better site design practices and techniques performed without regard to the criteria and conditions stated herein, many of which are discussed in Section 5.3, will not be awarded WQv reductions. However, it is important to remember that these practices, which reduce the overall impervious area on a site, already implicitly reduce the total amount of stormwater runoff generated by a site, and thus reduce the required WQv.

5.2.4 Reduction #1: Natural Area Preservation

Description
A reduction may be granted when undisturbed, natural areas are preserved on a site, thereby retaining their pre-development hydrologic and water quality characteristics. Under this reduction, a site designer can subtract preserved areas from total site area when computing water quality volume requirements. The area can be used as an undisturbed buffer for sheet flow discharge for site design Reduction #3, or for sheet flow of disconnected impervious areas under Reduction #5. An added benefit of the use of the natural area preservation reduction will be that the post-development peak discharges will be smaller for all design events, and hence other required control volumes and peak discharges (i.e., CPv and the locally regulated storm events) will be decreased due to lower post-development curve numbers or rational formula “C” values.

Rule
Subtract preserved natural areas from the total site area (A) when computing the water quality volume (WQv). The percent impervious (I) is held constant when calculating WQv. Areas qualifying for this reduction also receive a one-hundred percent (100%) TSS removal value in pollutant removal computations.

Design/Implementation Criteria
1. The vegetative target for the preserved natural area is undisturbed, mature forest (i.e., trees) with woody shrubs and understory vegetation. Areas that can be characterized as an early successional (i.e., immature) forest, consisting of a combination of grasses, vines, shrubs, tree saplings and possibly even a few mature trees will qualify for the reduction.
2. It is preferable that vegetation in the preserved natural area be native and non-invasive.
3. The local jurisdiction may require (or allow if requested by the property owner) restoration or enhancement of preserved natural areas that do not conform to the vegetative requirements stated in item 1 above at the time of development, in order to receive a reduction.
4. Areas that do not conform to the vegetative target defined in item 1 can be planted with vegetation as appropriate to achieve the vegetative requirements. For these areas, a

restoration plan must be submitted that is developed in accordance with the provisions and guidance presented in this manual. Guidance on the natural area restoration plan is provided below. A reduction will be granted only after approval of the plan.

5. The preserved natural area cannot be disturbed during project construction without prior approval by the local jurisdiction. If it is already disturbed prior to development or redevelopment, it can be restored as a natural area to receive a reduction.
6. The limits of disturbance on the site surrounding the preserved natural area shall be clearly shown on all construction drawings. The area must be staked in the field prior to issuance of a grading permit.
7. The preserved natural area shall be protected in perpetuity by deed restrictions, and/or a permanent preservation easement or conservation easement that is recorded with the deed.
8. If the area is not publicly owned, the easement must be held by a viable third party such as a land trust, land management company or utility. The purpose of the third party is to provide monitoring and oversight to ensure the perpetual protection of the area in accordance with the requirements of a conservation or preservation area. The organization shall:
    a. have the legal authority to accept and maintain such easements;
    b. be bona fide and in perpetual existence; and,
    c. have conveyance instruments that contain an appropriate provision for re-transfer in the event the organization becomes unable to carry-out its functions.
9. The easement and/or deed restriction must give the local jurisdiction the authority to enforce the easement or deed restriction terms.
10. The easement must clearly specify how the natural area vegetation shall be managed and how the boundaries of the area will be marked. (Note: managed turf areas, such as playgrounds and regularly maintained open areas, are not an acceptable form of vegetation management.)
11. The preserved natural area shall have a minimum contiguous area requirement of 0.25 acres.

Natural Area Restoration Plan Requirements

When vegetative restoration or enhancement of a preserved natural area is desired or required to receive the WQv reduction, the local jurisdiction may approve, or require, a natural area restoration plan. The plan must be submitted and approved by the local jurisdiction in order to receive the reduction. Natural area restoration plans must include the following information:

1. A drawing or plan that shows the location of the preserved natural area in relation to the existing or planned development. The plan should display the area proposed for restoration and the limits of disturbance, grubbing and grading (if permitted);
2. Best management practices for erosion prevention and sediment control during the vegetation restoration or enhancement (if not already submitted with a stormwater management plan for site development or redevelopment);
3. Verbiage and/or drawings indicating the species and density of proposed vegetation. Mortality must be accounted for in the initial planted density of all vegetation;
4. Verbiage, guidance, and/or drawings indicating the planting practices that will be utilized;
5. A maintenance and monitoring plan for one full growing season; and,
6. An implementation schedule.

Example 5-1 presents an example calculation of the preserved natural area reduction. The example utilizes the WQv equation presented in Chapter 3 of this manual.

Example 5-1. Natural Area Preservation Reduction Calculation
Proposed site: residential subdivision
Site area = 38 acres
Preserved natural area = 7 acres
Site impervious area = 13.8 acres
Rainfall depth for 85% storm event = 1.04 inches

Reduction Rule: Subtract the preserved natural area from the total site area when computing WQv. The percent impervious (I) is held constant.

I = site percent imperviousness = (13.8 acres)/(38 acres) * 100% = 36.3%

Runoff coefficient = Rv = 0.015 + 0.0092*(I) = 0.015 + 0.0092*(36.3%) = 0.35
Drainage area = total site area – preserved natural area = 38 acres – 7acres = 31 acres

Before reduction:
WQv = P*Rv*A/12 = (1.04 in)*(0.35)*(38 acres)/12 = 1.15 ac-ft

With reduction:
WQv = P*Rv*A/12 = (1.04 in)*(0.35)*(31 acres)/12 = 0.94ac-ft

The preserved natural area reduction resulted in a 18% reduction in the WQv required for the site. The area will also receive a 100% TSS removal value in the TSS calculation.

5.2.5 Reduction #2: Managed Open Space Preservation

Description

A reduction may be granted when areas of managed open space, typically reserved for passive recreation, are preserved on a site. Under this reduction, a site designer can subtract the preserved areas from total site area when computing water quality volume requirements. The area can be used for sheet flow of disconnected impervious areas under Reduction #5. An added benefit of the use of the managed preservation area reduction will be that the post-development peak discharges will be smaller for all design events, and hence water quantity control volumes (CPv and the locally regulated storm events) will be reduced due to lower post-development curve numbers or rational formula “C” values.

Rule

Subtract preserved managed areas from the total site area (A) when computing the water quality volume (WQv). The percent impervious (I) is held constant when calculating WQv. No TSS removal is received for areas in managed open space.

Design/Implementation Criteria

1. The managed area must have a passive recreational land use.
2. The minimum vegetative target for managed areas is grass covering 100% of the site. If the preserved area will have a land-use that requires vegetation that differs from this target, a legally-binding Management Plan must accompany the easement or deed restrictions. The Management Plan must show the vegetation management practices and other BMPs that will be utilized for maintenance of the area.
3. Impervious surfaces are prohibited in the reduction area.

4. Practices that have the potential to cause discharges of pollutants and sediment off-site are prohibited in the reduction area.
5. If the area is to be actively farmed, the Management Plan must be approved and monitored by the Natural Resource Conservation Service.
6. The preserved area shall be protected in perpetuity by deed restrictions, and/or a permanent preservation easement or conservation easement that is recorded with the deed.
7. If the area is not publicly owned, the easement must be held by a viable third party such as a land trust, land management company or utility. The purpose of the third party is to provide monitoring and oversight to ensure the perpetual protection of the area in accordance with the requirements of a conservation or preservation area. The organization shall:
   a. have the legal authority to accept and maintain such easements;
   b. be bona fide and in perpetual existence; and,
   c. have conveyance instruments that contain an appropriate provision for re-transfer in the event the organization becomes unable to carry-out its functions.
8. The easement and/or deed restriction must give the local jurisdiction the authority to enforce the easement or deed restriction terms.
9. The easement must clearly specify how vegetation shall be managed and how the boundaries of the area will be marked.
10. The managed area shall have a minimum contiguous area requirement of 0.5 acres.

Example 5-2. Managed Open Space Preservation Reduction Calculation

Proposed site: residential subdivision
Site area = 38 acres
Preserved managed area = 7 acres
Site impervious area = 13.8 acres
Rainfall depth for 85% storm event = 1.04 inches

Reduction Rule:: Subtract the preserved managed area from the total site area when computing WQv. The percent impervious (I) is held constant.

I = site percent imperviousness = (13.8 acres)/(38 acres) * 100% = 36.3%

Runoff coefficient = Rv = 0.015 + 0.0092*(I) = 0.015 + 0.0092*(36.3%) = 0.35

Drainage area = total site area – preserved managed area = 38 acres–7acres = 31 acres

Before reduction:
WQv = P*Rv*A/12 = (1.04 in)*(0.35)*(38 acres)/12 = 1.15 ac-ft

With reduction:
WQv = P*Rv*A/12 = (1.04 in)*(0.35)*(31 acres)/12 = 0.94 ac-ft

The managed open space reduction resulted in an 18% decrease in the WQv required for the site.

5.2.6 Reduction #3: Stream and Vegetated Buffers

Description

This reduction may be granted when stormwater runoff is effectively treated by a stream buffer or other vegetated buffer. Effective treatment constitutes passing runoff as overland sheet flow through an appropriately vegetated and forested buffer. Under this reduction, a site designer can subtract areas draining via overland flow to the buffer from total site area when computing water quality volume requirements. The area draining to the buffer and the buffer itself qualify for this reduction. In addition, the volume of runoff draining to the buffer can be subtracted from the channel protection volume (CPv).

Rule

Subtract areas draining via overland flow to the buffer from total site area when computing the water quality volume (WQv). The Rv value derived from impervious percentage is held constant when calculating WQv. For stream buffers with a grassed outer zone that have been established and managed in accordance with the provisions of Chapter 6 of this manual, the buffer and areas draining to the buffer qualify for the reduction and receive an eighty percent (80%) TSS reduction value. For buffers that are at least fifty (50) feet in width and are comprised entirely of undisturbed forest vegetation, the buffer itself can qualify for Reduction #1 as a natural conservation area or if preserved as managed open space can qualify for Reduction #2, while the areas draining to the buffer qualify for the buffer reduction and receive an eighty percent (80%) TSS reduction value.

Design/Implementation Criteria

1. This reduction is not applicable if the impervious area disconnection reduction (Reduction #5) is already being applied to the same area.
2. The portion of the buffer that is utilized for stormwater treatment must have a minimum buffer width of fifty (50) feet. If buffer averaging is utilized, portions of the buffer that have a width less than fifty (50) feet are not eligible to receive this reduction. Increases in buffer width and/or widths of forest vegetation are strongly encouraged.
3. At a minimum, buffers must be designed and managed (in perpetuity) in accordance with the requirements and policies for vegetated buffers presented in Chapter 6 of this manual.
4. Undisturbed, forested buffers that are at least fifty (50) feet wide can qualify for Reduction #1 as a natural conservation area. Areas preserved as managed open space can qualify for Reduction #2.
5. Stormwater runoff must enter the buffer as overland sheet flow. A level spreader can be utilized if sheet flow does not occur naturally, or if average contributing slope criteria cannot be met.
6. Flows greater than the flow occurring during the 1-year 24-hour storm can be passed through the buffer by a pipe or channel, but all flows less than that due to the 1-year 24-hour storm must pass as sheet flow over the buffer.
7. The minimum contributing length of sheet flow shall be ten (10) feet.
8. The maximum contributing length of sheet flow shall be two-hundred twenty-five (225) feet, with a maximum of one hundred fifty (150) feet for pervious surfaces, and seventy-five (75) feet for impervious surfaces.
9. The average contributing slope shall be three percent (3%) maximum unless a level spreader is used.
10. The design of the buffer treatment system must use appropriate methods for conveying flows above the annual recurrence (1-yr storm) event.

Example 5-3. Stream and Vegetated Buffer Reduction Calculation
Residential Subdivision
Site Area = 38 acres
Impervious Area = 13.8 acres
Area of undisturbed forested buffer having a 50' width = 2 acres
Area Draining to Buffer = 5 acres
Rainfall depth for 85% storm event = 1.04 inches

Reduction Rule: Subtract the area draining to the buffer when computing WQv. Since this is an undisturbed buffer area at least 50' in width, the area of the buffer can be considered a natural area under Reduction #1, and therefore can also be subtracted from the total site area when computing WQv. The percent impervious (I) is held constant.

I = site percent imperviousness = (13.8 acres)/(38 acres) * 100% = 36.3%
Runoff coefficient = Rv = 0.015 + 0.0092*(I) = 0.015 + 0.0092*(36.3%) = 0.35
Drainage area = Total site area – buffer area – area draining to buffer
Drainage area = 38 acres – 2 acre – 5 acres = 31 acres

Before reduction:
WQv = P*Rv*A/12 = (1.04 in)*(0.35)*(38 acres)/12 = 1.15 ac-ft

With reduction:
WQv = P*Rv*A/12 = (1.04 in)*(0.35)*(31 acres)/12 = 0.94 ac-ft

The buffer reduction resulted in a 18% reduction in the WQv required for the site. The buffer area will also receive a 100% TSS reduction value in the TSS calculation. The area draining to the buffer will receive an 80% TSS reduction value.

5.2.7 Reduction #4: Use of Vegetated Channels

This reduction may be granted when vegetated (grass) channels are used for water quality treatment. Site designers will be able to subtract the areas draining to a grass channel and the channel area itself from the total site area when computing water quality volume requirements. A vegetated channel may be able to fully meet the water quality volume requirements for certain kinds of low density residential development (see Reduction #6). An added benefit will be that the post-development peak discharges will likely be lower due to a longer time of concentration for the site.

Rule

Subtract the areas draining to a vegetated (grass) channel from total site area when computing the water quality volume (WQv). The percent impervious (I) shall be held constant when calculating WQv. Areas qualifying for this reduction also receive an eighty percent (80%) TSS removal value.

Design/Implementation Criteria

1. The vegetated channels must be located within a drainage, water quality or preservation easement.
2. The reduction shall only be applied to residential land uses that have a maximum density of three (3) dwelling units per acre.
3. The maximum flow velocity in the channel for the WQv design storm shall be less than or equal to one (1.0) feet per second.
4. The minimum residence time for the water quality storm shall be five (5) minutes.

5. The bottom width shall be a maximum of six (6) feet. If a larger channel is needed, use of a compound cross-section (i.e., a benched channel) is required.
6. The side slopes shall be 3:1 (horizontal:vertical) or flatter.
7. This reduction will not be granted if engineered grass channels are being used as a limited application structural stormwater control in order to meet the 80% TSS removal goal for WQv treatment.

Example 5-4. Vegetated Channels Reduction Calculation
Residential Subdivision
Site Area = 38 acres
Impervious Area = 13.8 acres
Area draining to vegetated channels = 12.5 acres
Rainfall depth for 85% storm event = 1.04 inches

Reduction Rule: Subtract the area draining to the vegetated channels when computing WQv. The percent impervious (I) is held constant.

I = site percent imperviousness = (13.8 acres)/(38 acres) * 100% = 36.3%
Runoff coefficient = Rv = 0.015 + 0.0092*(I) = 0.015 + 0.0092*(36.3%) = 0.35
Drainage area = Total site area – area draining to vegetated channels
Drainage area = 38 acres – 12.5 acres = 25.5acres

Before reduction:
WQv = P*Rv*A/12 = (1.04 in)*(0.35)*(38 acres)/12 = 1.15 ac-ft

With reduction:
WQv = P*Rv*A/12 = (1.04 in)*(0.35)*(25.5 acres)/12 = 0.77 ac-ft

The reduction resulted in a 33% reduction in the WQv required for the site. The area draining to the channel will also receive an 80% TSS reduction value in the TSS calculation.

5.2.8 Reduction #5: Impervious Area Disconnection

This reduction may be granted when impervious areas are disconnected from the stormwater control system via overland flow filtration/infiltration (i.e., pervious) zones. These pervious areas are incorporated into the site design to receive runoff from rooftops or other small impervious areas (e.g., driveways, small parking lots, etc). This can be achieved by grading the site to promote overland vegetative filtering or by providing infiltration or “rain garden” areas. If impervious areas are adequately disconnected in accordance with the criteria listed below, they can be deducted from the total site area when computing the water quality volume requirements. An added benefit will be that the post-development peak discharges will likely be lower due to a longer time of concentration for the site.

Rule

If impervious areas are adequately disconnected, they can be deducted from the total site area when computing the water quality volume (WQv). The percent impervious area (I) shall be held constant when calculating WQv. Areas qualifying for this reduction also receive an 80% TSS removal value in pollutant reduction computations.

Design/Implementation Criteria

1. For those areas draining directly to a buffer, either the impervious area disconnection reduction or the stream buffer reduction can be used, but not both.

2. Relatively permeable soils, soil amendments, or placed topsoil (hydrologic soil groups A and B) should be present in the pervious areas that receive discharges from disconnected impervious areas.
3. Impervious area disconnection reductions will not be given for areas that have, or will have after development, the land uses listed below:
   a. Developments or facilities that include on-site sewage disposal and treatment systems (i.e., septic systems), raised septic systems, subsurface discharges from a wastewater treatment plant, or land application of biosolids or animal waste;
   b. Landfills (demolition landfills, permitted landfills, closed-in-place landfills);
   c. Junkyards;
   d. Commercial or industrial facilities that store and/or service motor vehicles;
   e. Commercial greenhouses or landscape supply facilities;
   f. Agricultural facilities, farms, feedlots, and confined animal feed operations;
   g. Animal care facilities, kennels, and commercial/business developments or facilities that provide short-term or long-term care of animals; or,
   h. Other land uses deemed by the local jurisdiction to have the potential to generate higher than normal pollutant loadings.
4. The maximum contributing impervious flow path length to any single impervious area shall be 75 feet.
5. Downspouts shall be at least 10 feet away from the nearest accessible impervious surface (including off site impervious areas) to discourage "re-connections" or flow concentration along a paved edge.
6. The disconnection shall drain continuously through a vegetated channel, swale, or filter strip to the property line or to a structural stormwater control.
7. The length of the "disconnection" shall be equal to or greater than the contributing length.
8. The entire vegetative disconnection shall be on a slope less than or equal to 3 percent.
9. The impervious surface area to any single point discharge location shall not exceed 5,000 square feet.
10. There must be a note in the final plat that indicates the locations of the disconnected downspouts, and states that such downspouts "shall remain disconnected from the impervious surfaces and shall forever be discharged onto pervious surfaces".

Example 5-5. Impervious Area Disconnection Reduction Calculation

Office Building
Site Area = 3.0 acres
Impervious Area = 1.9 acres
Disconnected impervious area = 0.5 acres
Rainfall depth for 85% storm event = 1.04 inches

Reduction Rule: Subtract thedisconnected impervious areas from the total area when computing WQv. The percent impervious (I) is held constant.

I = site percent imperviousness = (1.9 acres)/(3 acres) * 100% = 63.3%
Runoff coefficient = Rv = 0.015 + 0.0092*(I) = 0.015 + 0.0092*(63.3%) = 0.60

Drainage area = Total site area – disconnected impervious area

Drainage area = 3 acres – 0.5 acres = 2.5 acres

Before rediction:
WQv = P*Rv*A/12 = (1.04 in)*(0.60)*(3 acres)/12 = 0.16 ac-ft

With reduction:
WQv = P*Rv*A/12 = (1.04 in)*(0.60)*(2.5 acres)/12 = 0.13 ac-ft
The reduction resulted in an 19% reduction in the WQv required for the site. The disconnected impervious areas will also receive an 80% TSS removal value in the TSS calculation.

5.2.9 Reduction #6: Environmentally Sensitive Large Lot Neighborhoods

This reduction is targeted toward large lot residential developments that implement a number of Better Site Design practices to reduce stormwater discharges from the development as a whole. This reduction may be granted when a group of environmental site design techniques are applied to low and very low density residential development (e.g., 1 dwelling unit per acre [du/ac] or lower). The reduction can eliminate the need for structural stormwater controls to treat water quality volume requirements.

Rule

The requirement for structural controls necessary to achieve the water quality volume treatment design criteria shall be waived for developments that meet the following criteria.

Design/Implementation Criteria

1. There are two development density options:
   a. The maximum density of the residential development shall be one (1) dwelling unit per acre, and shall have a total impervious cover footprint (including streets, sidewalks, and other impervious infrastructure) no greater than twelve percent (12%); or,
   b. The maximum density of the residential development shall be one (1) dwelling unit per two (2) acres, and shall have a total impervious cover footprint (including streets, sidewalks and other impervious infrastructure) no greater than fifteen percent (15%).
2. To verify the amount of development in an impervious area, the developer must provide one of the following with the stormwater management plan:
   a. The impervious footprints for roadways and lots, and the calculated percent imperviousness for the site. This option requires the developer to know the housing footprints and the general locations of each house on each lot so that driveway areas can be measured; or,
   b. The impervious footprint for roadways, the maximum expected impervious footprint per lot, and the calculated percent imperviousness for the development. The developer simply needs to know the size range of housing to be constructed in the development and to justify the per lot imperviousness based upon the housing size range anticipated.
3. Restrictive covenants, easements or other legal instruments must be used to limit imperviousness for each lot or development, or to set open space aside as perpetually undeveloped. The legal instrument must be conveyed to each property within the development, and must transfer accordingly with any subsequent property transfers.
4. Grass channels shall be used to convey runoff rather than curb and gutter.
5. Impervious areas shall be disconnected, in accordance with the criteria set forth in Reduction #5, to the maximum extent practicable.

5.3 Better Site Design Practices

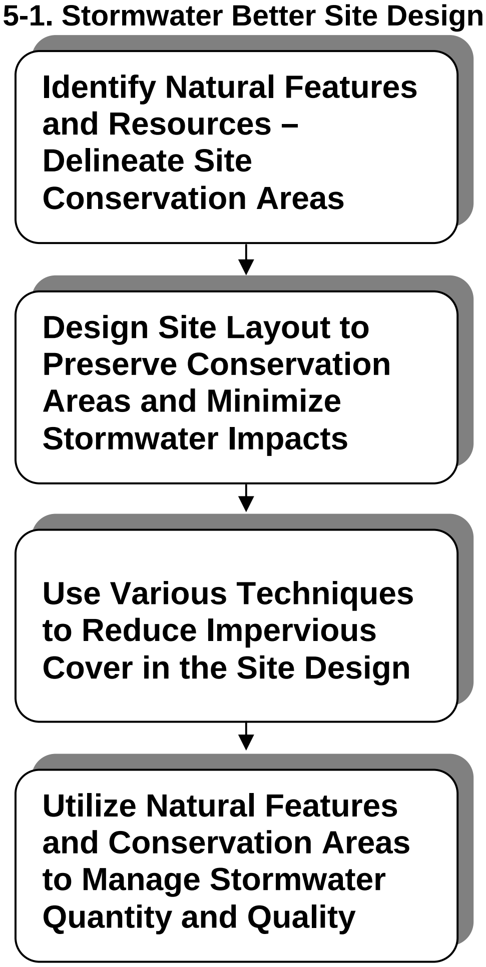
5.3.1 Overview

The remainder of this chapter has been developed to provide the developer and/or site designer detailed guidance on the use of a number of better site design practices. While the better site design practices presented herein are not required by the local jurisdictions, they are strongly encouraged. A number of these practices can be utilized to gain WQv reductions, as discussed previously in this chapter. However, beyond the reductions, there is strong incentive to utilize better site design practices that is provided by the use of the WQv approach. That is – the goal of many better site design practices is the reduction of imperviousness which, in the WQv approach, will reduce the volume of stormwater runoff required for treatment.

5.3.2 Incorporating Better Site Design Practices into Site Design Process

Better site design should be done in unison with the design and layout of stormwater infrastructure in attaining the stormwater management goals and criteria discussed in Chapters 1 and 3 of this manual. Figure 5-1. illustrates the four major steps of the site design process.

Figure 5-1. Stormwater Better Site Design Process



The first step in stormwater better site design involves identifying significant natural features and resources on a site such as undisturbed forest areas, stream buffers and steep slopes that should be preserved to retain some of the original hydrologic function of the site. Next, the site layout is designed such that these conservation areas are preserved and the impact of the development is minimized. A number of techniques can then be used to reduce the overall imperviousness of the development site. Finally, natural features and conservation areas can be utilized to serve stormwater quantity and quality management purposes.

5.3.3 Discussion of Better Site Design Practices

The stormwater better site design practices and techniques covered in this chapter are grouped into four categories and are listed below:

- **Conservation of Natural Features and Resources**
  - Preserve undisturbed natural areas
  - Preserve riparian (i.e., stream) buffers
  - Avoid development and grading in floodplains
  - Avoid steep slopes
  - Minimize development on porous or erodible soils

- **Lower Impact Site Design Techniques**
  - Fit design to the terrain
  - Locate development in less sensitive areas
  - Reduce limits of clearing and grading
  - Utilize open space development
  - Consider creative development design

- **Reduction of Impervious Cover**
  - Reduce roadway lengths and widths
  - Reduce building footprints
  - Reduce the parking footprint
  - Reduce setbacks and frontages
  - Use fewer or alternative cul-de-sacs
  - Create parking lot stormwater "islands"

- **Utilization of Natural Features for Stormwater Management**
  - Use buffers and undisturbed areas
  - Use natural drainageways instead of storm sewers
  - Use vegetated swales instead of curb and gutter
  - Drain rooftop runoff to pervious areas

More detail on each site design practice is provided in the Stormwater Better Site Design Practice Summary Sheets in subsections that follow. These summaries provide the key benefits of each practice, examples and details on how to apply them in site design.

5.3.4 Conservation of Natural Features and Resources

Conservation of natural features is integral to better site design. The first step in the better site design process is to identify and preserve the natural features and resources that can be used in the protection of water resources by reducing stormwater runoff, providing runoff storage, reducing flooding, preventing soil erosion, promoting infiltration, and removing stormwater pollutants. Some of the natural features that should be taken into account include:

- Areas of undisturbed vegetation;
- Floodplains and riparian areas;
- Ridgetops and steep slopes;
- Natural drainage pathways;
- Intermittent and perennial streams;
- Wetlands;
- Groundwater recharge/well head areas;
- Soils;
- Shallow bedrock or high water table;
- Other natural features or critical areas.

Some of the ways used to conserve natural features and resources described over the next several pages include the following methods, which correspond to the fact sheets that follow:

1. Preserve undisturbed natural areas
2. Preserve riparian buffers
3. Avoid floodplains
4. Avoid steep slopes
5. Minimize development on porous or erodible soils

Delineation of natural features is typically done very early in the development process, through an analysis of the features and resources on the site. From this site analysis, the preservation and protection of natural features can be integrated into the vision of the concept plan.

This space intentionally left blank

Better Site Design Practice #1:
Preserve Undisturbed Natural Areas

Conservation of Natural Features and Resources

Description: Important natural features and areas such as undisturbed forested and vegetated areas, natural drainageways, steep slopes, stream corridors, wetlands, erodible soils and other important site features should be delineated and placed into conservation areas.

KEY BENEFITS

- Preserves a portion of the site's natural hydrology prior to development.
- Can be used as filtering and infiltration zones for stormwater runoff from developed areas.
- Preserves some of the site's natural character and aesthetic features.
- May increase the value of the developed property.
- A stormwater site design reduction can be taken if the area complies with the criteria listed in section 5.2.

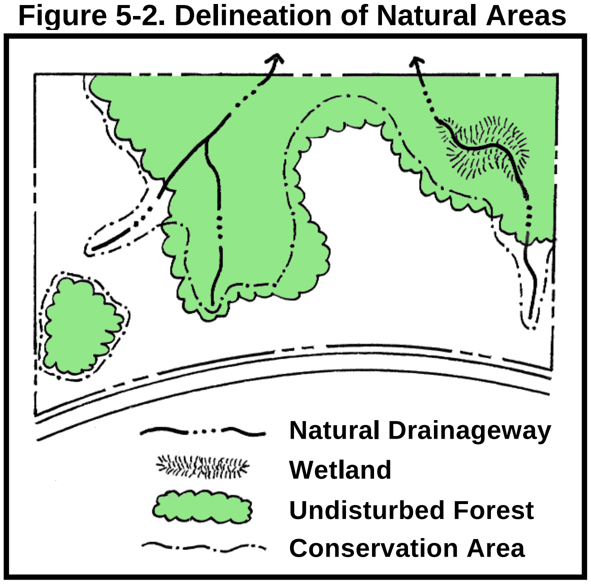
USING THIS PRACTICE

- ☑ Delineate natural areas before performing site layout and design.
- ☑ Ensure that conservation areas and native vegetation are protected in an *undisturbed state* throughout construction and occupancy.

Preserving natural conservation areas such as undisturbed forested and vegetated areas, natural drainageways, stream corridors and wetlands on a development site helps to preserve the original hydrology of the site and aids in reducing the generation of stormwater runoff and pollutants. Undisturbed vegetated areas also promote soil stabilization and provide for filtering, infiltration and evapotranspiration of runoff.

Natural conservation areas are typically identified through a site analysis using maps and aerial/satellite photography, or by conducting a site visit. These areas should be delineated before any site design, clearing or construction begins. When done before the concept plan phase, the planned conservation areas can be used to guide the layout of the site. Figure 5-2 shows a site map with undisturbed natural areas delineated.

Figure 5-2. Delineation of Natural Areas



Preserved natural areas should be incorporated into site plans and clearly marked on all construction and grading plans to ensure that equipment is kept out of these areas and that native vegetation is kept in an undisturbed state. Prior to construction, the boundaries of each natural area should be mapped by carefully determining the limit which should not be crossed by construction activity.

Once established, natural areas should be managed by a responsible party that is able to maintain the areas in a natural state in perpetuity. Typically, conservation areas are protected by legally enforceable deed restrictions, conservation easements, and maintenance agreements. If the natural area is utilized for WQv reductions, the use of a responsible third party is required to achieve the perpetual preservation of the area. Refer to Reduction #1 for more information on the Natural Area Preservation Reduction.

Better Site Design Practice #2:
Preserve Riparian Buffers

Conservation of Natural Features and Resources

Description: Preserve naturally vegetated buffers along perennial streams, rivers, lakes, and wetlands.

KEY BENEFITS	USING THIS PRACTICE
• Can be used as nonstructural stormwater filtering and infiltration zones. • Keeps structures out of the floodplain and provides a right-of-way for large flood events. • Helps to preserve riparian ecosystems and habitats. • A stormwater site design reduction can be taken if it fulfills the criteria listed in section 5.2.	☑ Delineate and preserve naturally vegetated riparian buffers. ☑ Ensure that buffers are established, maintained and protected in accordance with guidance set forth in Volume II Chapter 6.

As discussed in Chapter 6, buffers are a special type of natural conservation area located along a stream, wetland or pond/lake where development is restricted or prohibited. In the local jurisdictions, vegetated buffers are required on all waterbodies that can be designated as "community waters" as defined in this manual. Such buffers must be established, maintained and protected in accordance with the provisions of Chapter 6 of this manual. This section simply provides some general information about buffers.

Figure 5-3. Riparian Stream Buffer

The primary function of buffers is to protect and physically separate a waterbody from future disturbance or encroachment. If properly designed, a buffer can provide stormwater management functions, can act as a right-of-way during floods, and can sustain the integrity of stream ecosystems and habitats. An example of a riparian stream buffer is shown in Figure 5-3. The buffer requirements include provisions for a minimum fifty (50) foot dual-zone, forested and grassed buffer along streams, and a minimum twenty-five (25) foot inner-zone forested or grass buffer around wetlands and ponds/lakes, respectively.

In general, forested zones of buffers should be maintained and reforestation should be encouraged where no wooded buffer exists. Chapter 6 of this manual contains provisions and guidance for buffer reforestation (herein called "enhancement"). Proper enhancement of forested areas should include all layers of the forest plant community, including understory shrubs and groundcover, not just trees. Native vegetation is required in forested zones. Impervious areas are prohibited in all areas of the buffer.

Better Site Design Practice #3:
Avoid Floodplains

Conservation of Natural Features and Resources

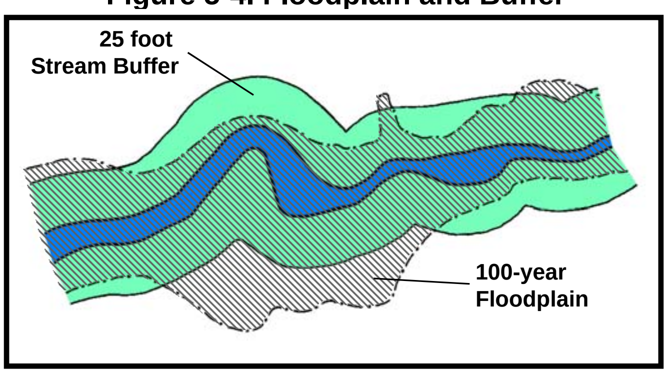
Description: Development in floodplain areas should be avoided to minimize potential property damages and safety risks, and to allow the natural stream corridor to accommodate flood flows.

KEY BENEFITS	USING THIS PRACTICE
• Provides a natural right-of-way and temporary storage for large flood events. • Keeps people and structures out of potentially flooded areas. • Helps to preserve riparian ecosystems and habitats. • Can be combined with riparian buffer protection to create linear greenways.	☑ Be aware of the local jurisdiction's floodplain development requirements. ☑ Do not encroach into designated floodplain areas. Maps are available from the local jurisdiction.

Floodplains are the low-lying flat lands that border streams and rivers. When a stream reaches its capacity and overflows its channel after storm events, the floodplain provides the natural storage and conveyance areas for these excess flows. When left in a naturally vegetated state with forest, shrubs and other woody vegetation, floodplains can provide a reduction in discharge velocities and peak discharges rates during flood events. Floodplains also play an important role in reducing sedimentation and filtering runoff, and provide habitat for both aquatic and terrestrial life. Development in floodplain areas can reduce the ability of the floodplain to convey stormwater, potentially causing safety problems or significant damage to the site in question, as well as to both upstream and downstream properties. As participant communities of the National Flood Insurance Program (NFIP), the local jurisdictions regulate the use of floodplains to minimize the risk to human life as well as to avoid flood damage to structures and property.

As such, all floodplains should be avoided on a development site. Ideally, the entire 100-year floodplain should be avoided for clearing or building activities, and should be preserved in a natural undisturbed state where possible. At a minimum, developers should also ensure that their site design complies with the local jurisdiction's floodplain requirements. Floodplain maps and flood elevation profiles can be obtained from the local jurisdiction.

Figure 5-4. Floodplain and Buffer



Floodplain protection is complementary to riparian buffer preservation. Both practices preserve stream corridors in a natural state and allow for the protection of vegetation and habitat. Depending on the site topography, 100-year floodplain boundaries may lie inside or outside of a preserved riparian buffer corridor, as shown in Figure 5-4.

Better Site Design Practice #4:
Avoid Steep Slopes

Conservation of Natural Features and Resources

Description: Development on steep slopes should be avoided due to the potential for soil erosion and increased sediment loading to nearby streams. Excessive grading and flattening of hills and ridges should be minimized.

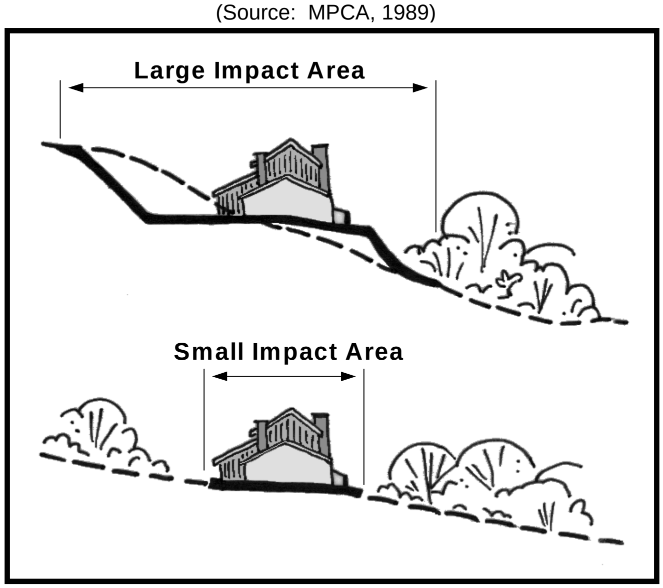
KEY BENEFITS	USING THIS PRACTICE
• Preserving steep slopes helps to prevent soil erosion and degradation of stormwater runoff. • Steep slopes can be kept in an undisturbed natural condition to help stabilize hillsides and soils. • Building on flatter areas will reduce the need for cut-and-fill and grading.	☑ Avoid development on steep slope areas, especially those with a grade of 15% or greater. ☑ Fit the development into the natural terrain, as opposed to modifying the terrain to fit the development. ☑ Minimize grading and flattening of hills and ridges.

Development in steep slope areas has the potential to cause excessive soil erosion and stormwater runoff during and after construction. Past studies by the Soil Conservation Service (now Natural Resource Conservation Service) and others have shown that soil erosion is significantly increased on slopes of 15 percent or greater. In addition, greater areas of soil and land area are disturbed when development is located on steep slopes as compared to flatter slopes. This is demonstrated in Figure 5-5.

Therefore, development on slopes with a grade of 15 percent or greater should be avoided to limit soil loss, erosion, excessive stormwater runoff, and the degradation of surface water. Excessive grading should be avoided on all slopes, as should the flattening of hills and ridges. Steep slopes should be kept in an undisturbed natural condition to help stabilize hillsides and soils.

On slopes greater than 25 percent, no development, regrading, or stripping of vegetation should be considered unless the disturbance is for roadway crossings or utility construction and it can be demonstrated that the roadway or utility improvements are absolutely necessary in the sloped area.

Figure 5-5. Impacts of Development on Slopes
(Source: MPCA, 1989)



Better Site Design Practice #5:

Minimize Development on Porous and Erodible Soils

Conservation of Natural Features and Resources

Description: Porous soils such as sand and gravels provide an opportunity for groundwater recharge of stormwater runoff and should be preserved as a potential stormwater management option. Unstable or easily erodible soils should be avoided because they are more likely to erode.

KEY BENEFITS

- Areas with highly permeable soils can be used for infiltration of stormwater runoff. WQv reductions can be taken if the area complies with the criteria listed in section 5.2, potentially for a Natural Area Preservation reduction or Impervious Area Disconnection reduction.
- Avoiding highly erodible or unstable soils can prevent erosion and sedimentation problems and water quality degradation.

USING THIS PRACTICE

- ☑ Use soil surveys to determine site soil types.
- ☑ Leave areas of porous or highly erodible soils as undisturbed preservation areas.

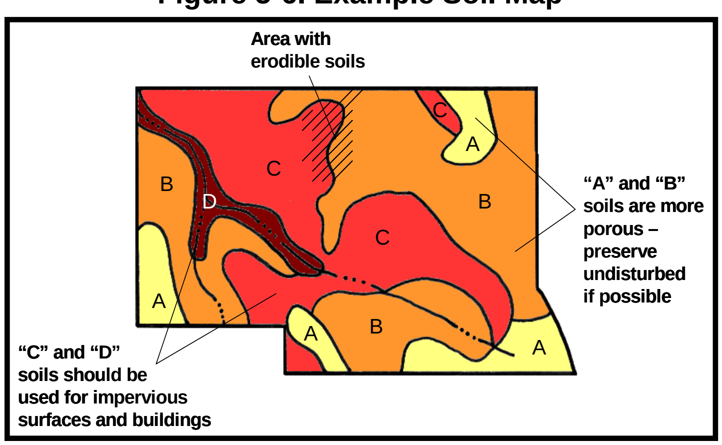
Infiltration of stormwater into the soil reduces both the volume and peak discharge of runoff from a given rainfall event, and also provides for water quality treatment and groundwater recharge. Soils with maximum permeability (hydrologic soil group A and B soils, such as sands and sandy loams) allow for the most infiltration of runoff into the subsoil. Thus, areas of a site with these soils should be conserved as much as possible and these areas should ideally be incorporated into undisturbed natural or open space areas. Conversely, buildings and other impervious surfaces should be located on those portions of the site with the *least* permeable soils.

Similarly, land disturbance and building of structures should not occur on areas of a site with highly erodible or unstable soils. By avoiding these soil types, erosion and sedimentation problems as well as potential future structural problems can be avoided. These areas should be left in an undisturbed and vegetated condition.

Soils on a development site should be mapped in order to preserve areas with porous soils, and to identify those areas with unstable or erodible soils as shown in Figure 5-6. The local jurisdiction soil surveys can provide a considerable amount of information relating to all relevant aspects of soils. Soil surveys are available from the local National Resource Conservation Service office.

General soil types should be delineated on concept site plans to guide site layout and the placement of buildings and impervious surfaces.

Figure 5-6. Example Soil Map



5.3.5 Low Impact Site Design Techniques

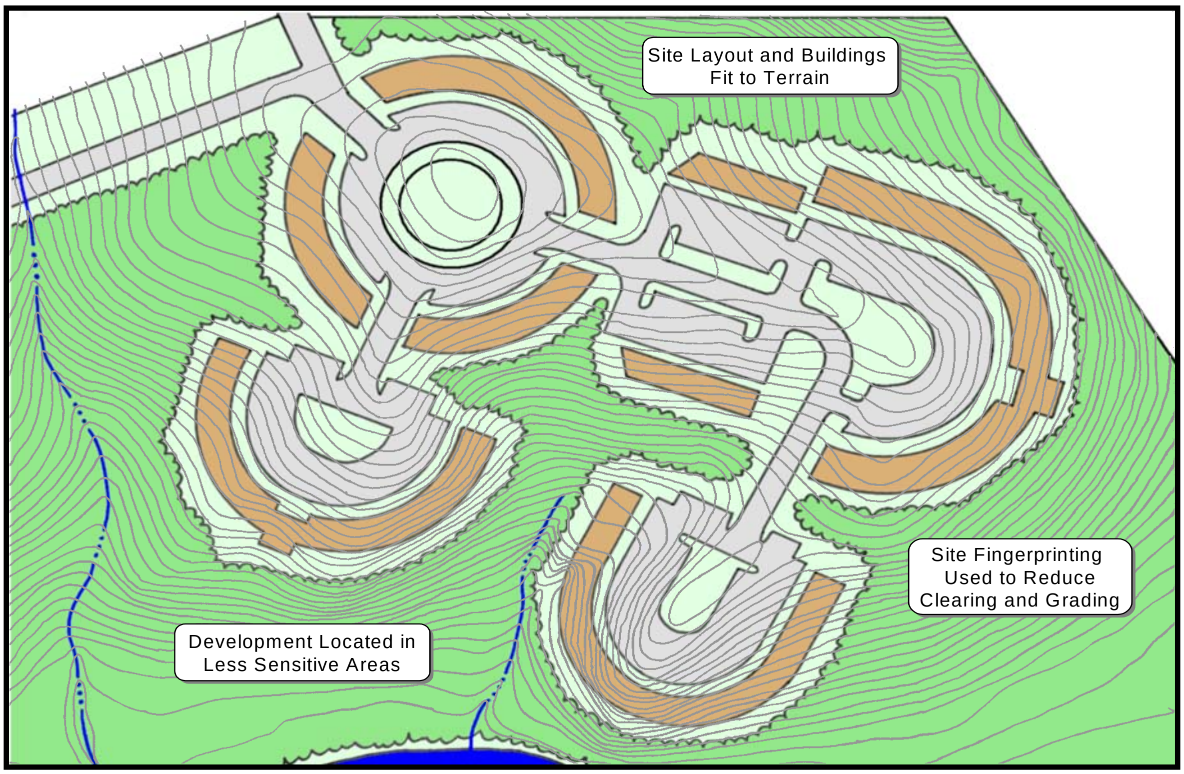
After a site analysis has been performed and conservation areas have been delineated, there are numerous opportunities in the site design and layout phase to reduce both water quantity and quality impacts of stormwater runoff. These primarily deal with the location and configuration of impervious surfaces or structures on the site and include the following practices and techniques covered over the next several pages:

6. Fit the Design to the Terrain
7. Locate Development in Less Sensitive Areas
8. Reduce Limits of Clearing and Grading
9. Utilize Open Space Development
10. Consider Creative Development Design

The goal of low impact site design techniques is to lay out the elements of the development project in such a way that the site design (i.e. placement of buildings, parking, streets and driveways, lawns, undisturbed vegetation, buffers, etc.) is optimized for effective stormwater management. That is, the site design takes advantage of the site's natural features, including those placed in conservation areas, as well as any site constraints and opportunities (topography, soils, natural vegetation, floodplains, shallow bedrock, high water table, etc.) to prevent both on-site and downstream stormwater impacts.

Figure 5-7. shows a development that has utilized several low impact site design techniques in its overall layout and design.

Figure 5-7. Example of Lower Impact Site Design Techniques



Better Site Design Practice #6:
Fit Design to the Terrain

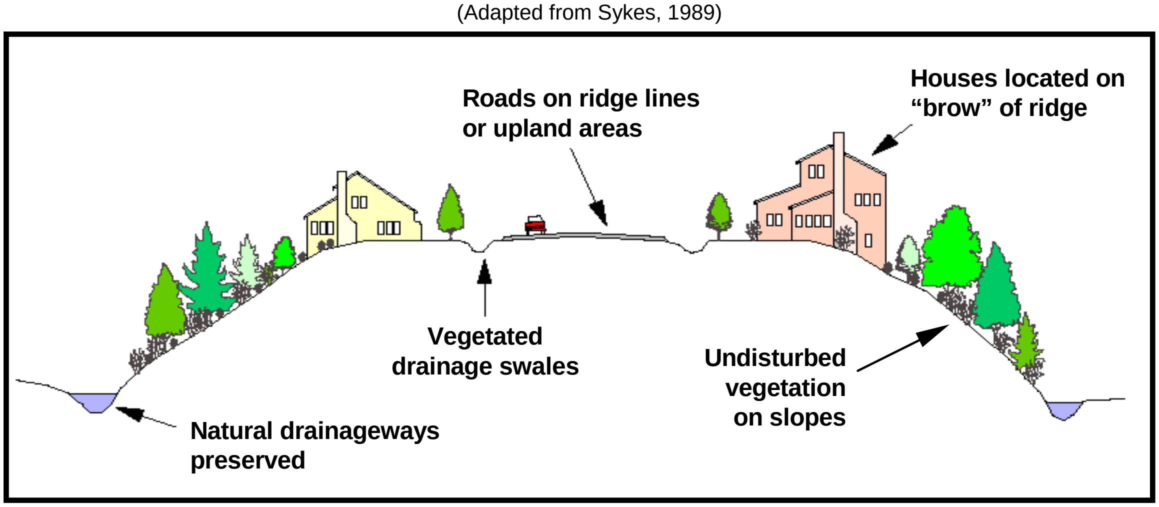
Low Impact
Site Design Techniques

Description: The layout of roadways and buildings on a site should generally conform to the landforms on a site. Natural drainageways and stream buffer areas should be preserved by designing road layouts around them. Buildings should be sited to utilize the natural grading and drainage system and avoid the unnecessary disturbance of vegetation and soils.

KEY BENEFITS	USING THIS PRACTICE
• Helps to preserve the natural hydrology and drainageways of a site. • Reduces the need for grading and land disturbance. • Provides a framework for site design and layout.	☑ Develop roadway patterns to fit the site terrain. ☑ Locate buildings and impervious surfaces away from steep slopes, drainageways, and floodplains.

All site layouts should be designed to conform with or "fit" the natural landforms and topography of a site. This helps to preserve the natural hydrology and drainageways on the site, as well as reduces the need for grading and disturbance of vegetation and soils. Figure 5-8 illustrates the placement of roads and homes in a residential development.

Figure 5-8. Preserving the Natural Topography of the Site
(Adapted from Sykes, 1989)



Roadway patterns on a site should match the terrain. In rolling or hilly terrain, streets should be designed to follow natural contours to reduce clearing and grading. Street hierarchies with local streets branching from collectors in short loops, and cul-de-sacs located along ridgelines help to prevent the crossing of streams and drainageways as shown in Figure 5-9. In flatter areas, a traditional grid pattern of streets or "fluid" grids which bend and may be interrupted by natural drainageways may be more appropriate (see Figure 5-10). In either case, buildings and impervious surfaces should be kept off of steep slopes, away from natural drainageways, and out of floodplains and other lower lying areas. In addition, the major axis of buildings should be oriented parallel to existing contours.

Figure 5-9. Example Subdivision Design for Hilly or Steep Terrain

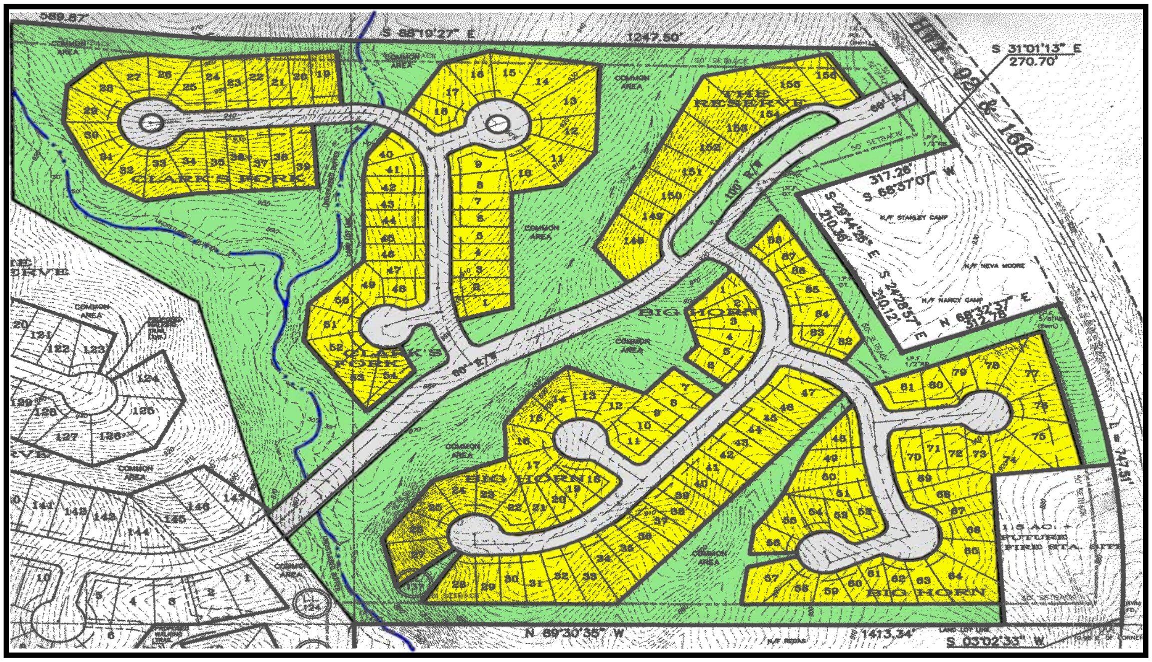
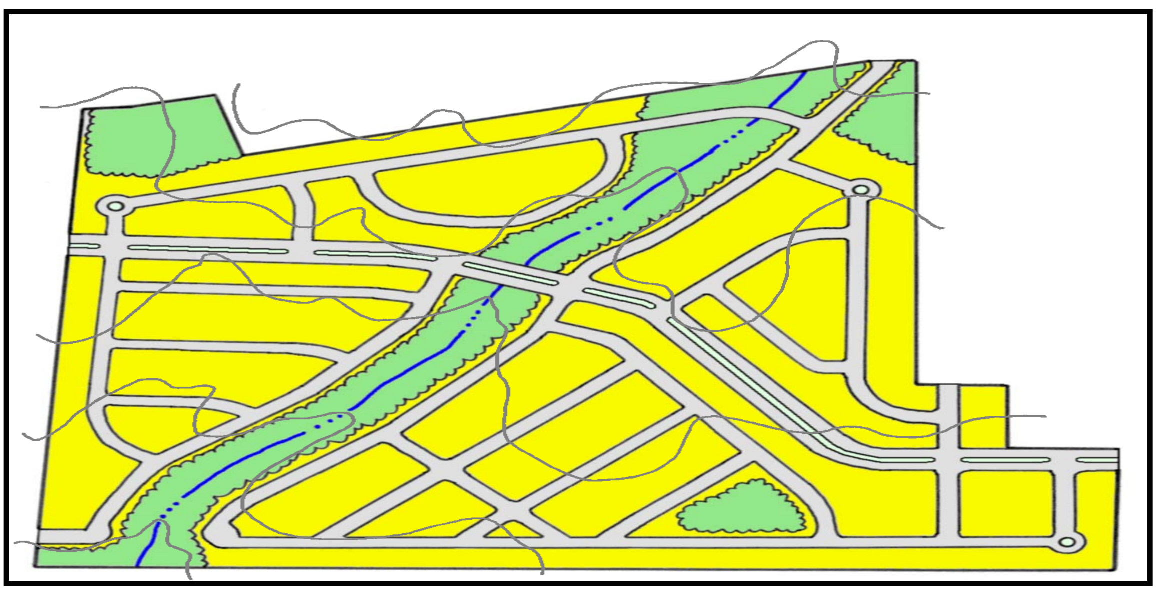


Figure 5-10. Example Subdivision Design for Flat Terrain



Better Site Design Practice #7:

Locate Development in Less Sensitive Areas

**Low Impact
Site Design Techniques**

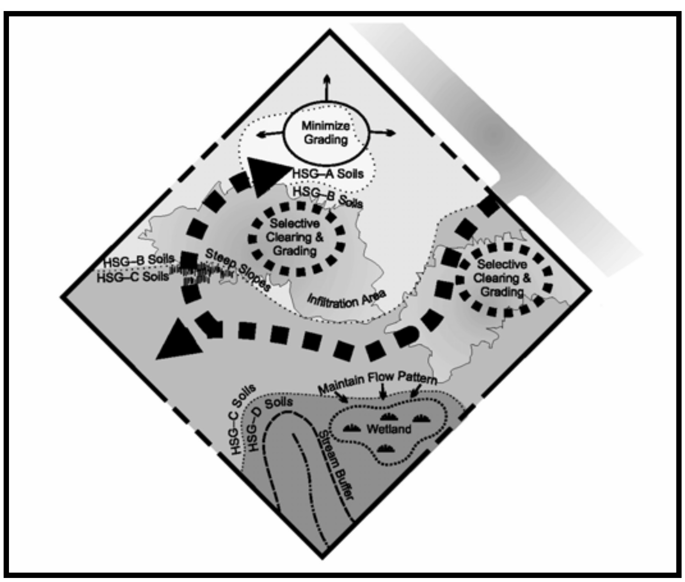
Description: To minimize the hydrologic impacts on the existing site, the area of development should be located in areas that are less sensitive to disturbance or have a lower value in terms of hydrologic function.

KEY BENEFITS	USING THIS PRACTICE
• Helps to preserve the natural hydrology and drainageways of a site. • Makes the most efficient use of natural site features for preventing and mitigating stormwater impacts. • Provides a framework for site design and layout.	☑ Lay out the site design to minimize the hydrologic impact of structures and impervious surfaces.

In much the same way that a development should be designed to conform to terrain of the site, a site layout should also be designed so that the areas of development are placed in the locations of the site that minimize the hydrologic impact of the project. This is accomplished by steering development to areas of the site that are less sensitive to land disturbance or have a lower value in terms of hydrologic function using the following methods:

- Locate buildings and impervious surfaces away from stream corridors, wetlands and natural drainageways. Use buffers to preserve and protect riparian areas and corridors.
- Areas of the site with porous soils should left in an undisturbed condition and/or used as stormwater runoff infiltration zones. Buildings and impervious surfaces should be located in areas with less permeable soils.

Figure 5-11. Guiding Development to Less Sensitive Areas of a Site
(Source: Prince George's County, MD, 1999)



- Avoid construction on areas with steep slopes or unstable soils.
- Minimize the clearing of areas with dense tree canopy or thick vegetation. Ideally, preserve these as natural conservation areas
- Ensure that natural drainageways and flow paths are preserved, where possible. Avoid the filling or grading of natural depressions and ponding areas.

Figure 5-11 shows a development site where the natural features have been mapped in order to delineate the sensitive areas. Through careful site planning, sensitive areas can be set aside as natural open space areas In many cases, such areas can be used as buffer spaces between land uses on the site or between adjacent sites.

Better Site Design Practice #8:
Reduce Limits of Clearing and Grading

**Low Impact
Site Design Techniques**

Description: Clearing and grading of the site should be limited to the minimum amount needed for the development and road access. Site footprinting should be used to disturb the smallest possible land area on a site.

KEY BENEFITS	USING THIS PRACTICE
• Preserves more undisturbed natural areas on a development site. • Techniques can be used to help protect natural conservation areas and other site features.	☑ Establish the limits of disturbance for all development activities on construction plans. ☑ Use site footprinting to minimize clearing and land disturbance.

Minimal disturbance methods should be used to limit the amount of clearing and grading that takes place on a development site, preserving more of the undisturbed vegetation and natural hydrology of a site. These methods include:

- Establishing a limit of disturbance (LOD) based on grading requirements. These maximum distances should reflect reasonable construction techniques and equipment needs together with the physical situation of the development site such as slopes or soils. LOD distances may vary by type of development, size of lot or site, and by the specific development feature involved. The LOD should be shown on plans and staked in the field to ensure that grading contractors stay out of the area.
- Using site "footprinting" which maps all of the limits of disturbance to identify the smallest possible land area on a site which requires clearing or land disturbance. Examples of site footprinting are illustrated in Figures 5-12 and 5-13.
- Fitting the site design to the terrain.
- Using special procedures and equipment which reduce land disturbance.

Figure 5-12. Example of Limits of Clearing
(Source: DDNREC, 1997)

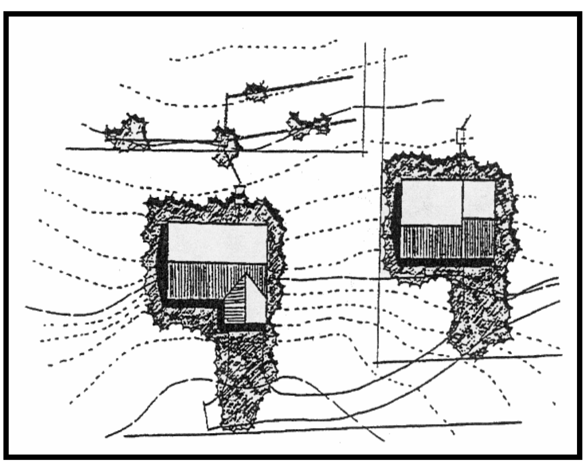


Figure 5-13. Example of Site Footprinting

Better Site Design Practice #9:
Utilize Open Space Development

Low Impact
Site Design Techniques

Description: Open space site designs incorporate smaller lot sizes to reduce overall impervious cover while providing more undisturbed open space and protection of water resources.

KEY BENEFITS	USING THIS PRACTICE
• Preserves conservation areas. • Can be used to preserve natural hydrology and drainagways. • Can be used to help protect natural conservation areas and other site features. • Reduces the need for grading and land disturbance. • Reduces infrastructure needs and overall development costs.	☑ Use a site design which concentrates development and preserves open space and natural areas of the site.

Open space development, also known as *conservation development* or *clustering*, is a better site design technique that concentrates structures and impervious surfaces in a compact area in one portion of the development site in exchange for providing open space and natural areas elsewhere on the site. Typically smaller lots and/or nontraditional lot designs are used to cluster development and create more conservation areas on the site.

Open space developments have many benefits compared with conventional commercial developments or residential subdivisions: they can reduce impervious cover, stormwater pollution, construction costs, and the need for grading and landscaping, while providing for the conservation of natural areas. Figures 5-14 presents an example of the concept of open space site design for a residential area. Figure 5-15 provides an example of an existing open space development.

Along with reduced imperviousness, open space designs provide a host of other environmental benefits that most conventional designs lack. These developments reduce potential pressure to encroach on conservation and buffer areas because enough open space is usually reserved to accommodate these protection areas. Since less land is cleared during the construction process, alteration of the natural hydrology and the potential for soil erosion are also greatly diminished. Perhaps most importantly, open space design reserves 25 to 50 percent of the development site in conservation areas that would not otherwise be protected.

Open space developments can also be significantly less expensive to build than conventional projects. Most of the cost savings are due to reduced infrastructure cost for roads and stormwater management controls and conveyances. While open space developments are frequently less expensive to build, developers find that these properties often command higher prices than those in more conventional developments. Several studies estimate that residential properties in open space developments garner premiums that are higher than conventional subdivisions and moreover, sell or lease at an increased rate.

Once established, common open space and natural conservation areas must be managed by a responsible party able to maintain the areas in a natural state in perpetuity. Typically, the conservation areas are protected by legally enforceable deed restrictions, conservation easements, and maintenance agreements. Detailed guidance and example plans can be found in the book, “Conservation Design for Subdivisions”, by Randall Arendt.

Figure 5-14. Open Space Subdivision Site Design Example

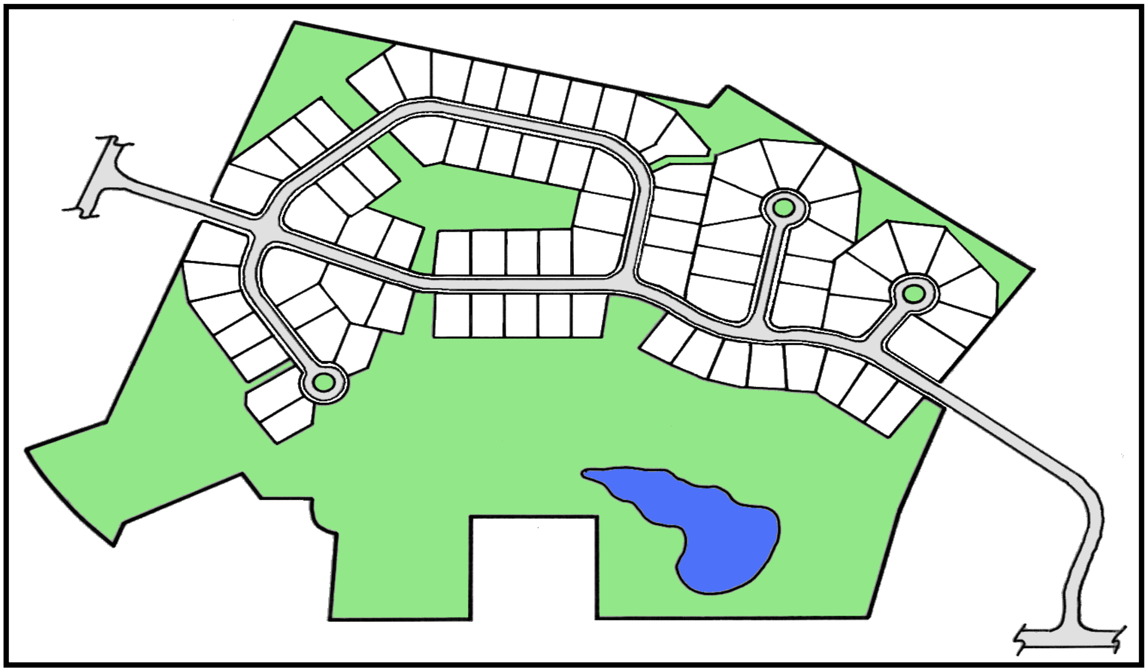


Figure 5-15. Aerial View of an Open Space Subdivision

Better Site Design Practice #10:
Consider Creative Development Design

Low Impact Site Design Techniques

Description: Planned Unit Developments (PUDs) allow a developer or site designer the flexibility to design a residential, commercial, industrial, or mixed-use development in a fashion that best promotes effective stormwater management and the protection of environmentally sensitive areas.

KEY BENEFITS	USING THIS PRACTICE
• Allows flexibility to developers to implement creative site designs which include stormwater better site design practices. • May be useful for implementing an open space development.	☑ Check with the local jurisdiction to determine the type and nature of deviations allowed and other criteria for receiving PUD approval.

A Planned Unit Development (PUD) is a type of planning approval available in some communities which provides greater design flexibility by allowing deviations from the typical development standards required by the local zoning code with additional variances or zoning hearings.

The intent is to encourage better designed projects through the relaxation of some development requirements, in exchange for providing greater benefits to the community. PUDs can be used to implement many of the other stormwater better site design practices covered in this Manual and to create site designs that maximize natural nonstructural approaches to stormwater management.

Examples of the types of zoning deviations which are often allowed through a PUD process include:

- Allowing uses not listed as permitted, conditional or accessory by the zoning district in which the property is located
- Modifying lot size and width requirements
- Reducing building setbacks and frontages from property lines
- Altering parking requirements
- Allowing narrower roads or the use of alleys
- Increasing building height limits

Many of these changes are useful in reducing the amount of impervious cover on a development site (see Better Site Design Practices #11 through #16).

5.3.6 Reduction of Impervious Cover

The amount of impervious cover, i.e. rooftops, parking lots, roadways, sidewalks and other hardened surfaces that do not allow rainfall to infiltrate into the soil, is an essential factor to consider in better site design for stormwater management. Increased impervious cover means increased stormwater generation and increased pollutant loadings.

By reducing the area of total impervious surface on a site, a site designer can directly reduce the volume of stormwater runoff and associated pollutants that are generated by a site. It can also reduce the size and cost of infrastructure for stormwater drainage, conveyance, and control and treatment. Some of the ways that impervious cover can be reduced in a development include:

- # 11. Reduce Roadway Lengths and Widths
- # 12. Reduce Building Footprints
- # 13. Reduce the Parking Footprint
- # 14. Reduce Setbacks and Frontages
- # 15. Use Fewer or Alternative Cul-de-Sacs
- # 16. Create Parking Lot Stormwater Islands

Figure 5-16. shows an example of a residential subdivision that employed several of these principles to reduce the overall imperviousness of the development. The next several pages cover these methods in more detail.

Figure 5-16. Examples (clockwise from upper left): (a) Cul-de-sac with Landscaped Island; (b) Narrower Residential Street; (c) Landscape Median in Roadway; and (d) "Green" Parking Lot with Landscaped Islands

Better Site Design Practice #11:
Reduce Roadway Lengths and Widths

Reduction of Impervious Cover

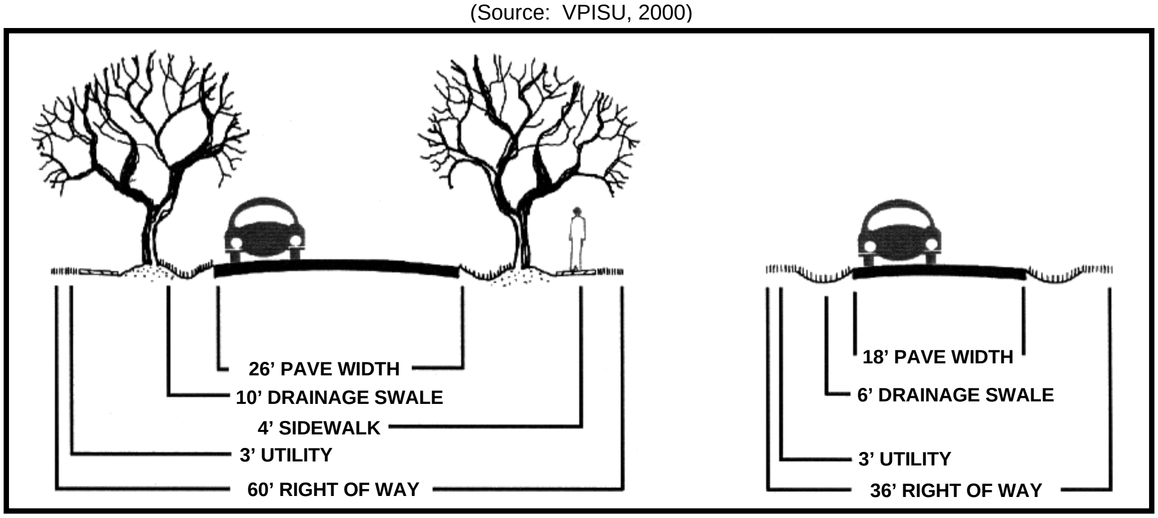
Description: Roadway lengths and widths should be minimized on a development site where possible to reduce overall imperviousness.

KEY BENEFITS	USING THIS PRACTICE
• Reduces the amount of impervious cover and associated runoff and pollutants. • Reduces the costs associated with road construction and maintenance.	☑ Consider different site and road layouts that reduce overall street length. ☑ Minimize street widths by using narrower street designs.

The use of alternative road layouts that reduce the total linear length of roadways can significantly reduce overall imperviousness of a development site. Site designers are encouraged to analyze different site and roadway layouts to see if they can reduce overall street length. The length of local cul-de-sacs and cross streets should be shortened to a maximum of 200 ADT (average trips per day) to minimize traffic and road noise so that shorter setbacks may be employed.

In addition, residential streets and private streets within commercial and other development should be designed for the minimum required pavement width needed to support travel lanes, on-street parking, and emergency access. Figure 5-17 shows an option for narrower street designs. Many times on-street parking can be reduced to one lane or eliminated on local access roads with less than 200 ADT on cul-de-sac streets and 400 ADT on two-way loops. One-way single-lane loop roads are another way to reduce the width of lower traffic streets.

Figure 5-17. Potential Design Options for Narrower Roadway Widths
(Source: VPISU, 2000)



Better Site Design Practice #12:
Reduce Building Footprints

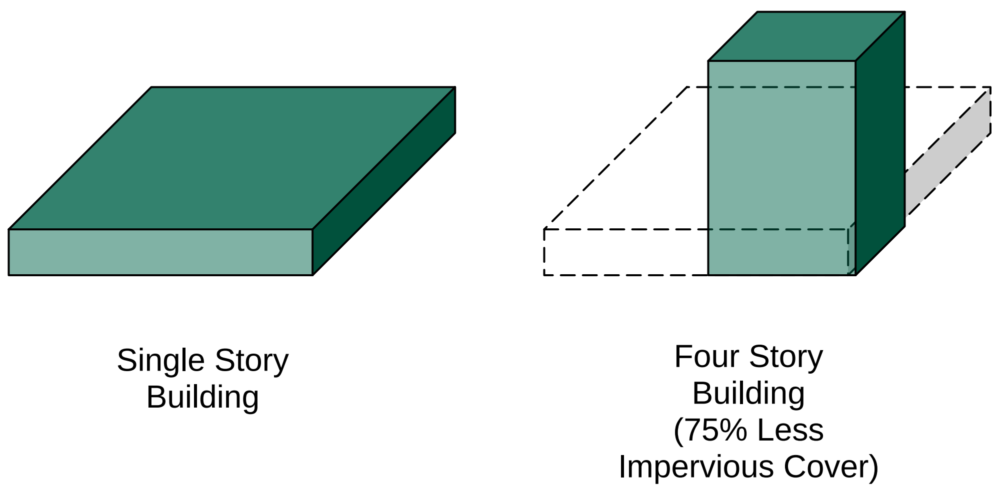
Reduction of Impervious Cover

Description: The impervious footprint of commercial buildings and residences can be reduced by using alternate or taller buildings while maintaining the same floor to area ratio.

KEY BENEFITS	**USING THIS PRACTICE**
• Reduces the amount of impervious cover and associated runoff and pollutants.	☑ Use alternate or taller building designs to reduce the impervious footprint of buildings.

In order to reduce the imperviousness associated with the footprint and rooftops of buildings and other structures, alternative and/or vertical (taller) building designs should be considered. Consolidate functions and buildings, as required, or segment facilities to reduce the footprint of individual structures. Figure 5-18 shows the reduction in impervious footprint from a taller building as opposed to a single story building.

Figure 5-18. Impervious Cover Comparison



Better Site Design Practice #13:
Reduce the Parking Footprint

Reduction of Impervious Cover

Description: Reduce the overall imperviousness associated with parking lots by providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, parking decks, and using porous paver surfaces or porous concrete in overflow parking areas where feasible and possible.

KEY BENEFITS	USING THIS PRACTICE
• Reduces the amount of impervious cover and associated runoff and pollutants generated	☑ Reduce the number of parking spaces ☑ Minimize stall dimensions ☑ Consider parking structures and shared parking ☑ Use alternative porous surface for overflow areas

Setting maximums for parking spaces, minimizing stall dimensions, using structured parking, encouraging shared parking and using alternative porous surfaces can all reduce the overall parking footprint and site imperviousness.

Many parking lot designs result in far more spaces than actually required. This problem is exacerbated by a common practice of setting parking ratios to accommodate the highest hourly parking during the peak season. By determining average parking demand instead, a lower maximum number of parking spaces can be set to accommodate most of the demand. Table 5-3 provides examples of conventional parking requirements and compares them to average parking demand.

Table 5-3. Conventional Minimum Parking Ratios

(Source: www.stormwatercenter.net)

Land Use	Parking Requirement		Actual Average Parking Demand
	Parking Ratio	Typical Range	
Single family homes	2 spaces per dwelling unit	1.5–2.5	1.11 spaces per dwelling unit
Shopping center	5 spaces per 1000 ft^2 GFA	4.0–6.5	3.97 per 1000 ft^2 GFA
Convenience store	3.3 spaces per 1000 ft^2 GFA	2.0–10.0	--
Industrial	1 space per 1000 ft^2 GFA	0.5–2.0	1.48 per 1000 ft^2 GFA
Medical/ dental office	5.7 spaces per 1000 ft^2 GFA	4.5–10.0	4.11 per 1000 ft^2 GFA
GFA = Gross floor area of a building without storage or utility spaces.			

Another technique to reduce the parking footprint is to minimize the dimensions of the parking spaces. This can be accomplished by reducing both the length and width of the parking stall. Parking stall dimensions can be further reduced if compact spaces are provided. While the trend toward larger sport utility vehicles (SUVs) is often cited as a barrier to implementing stall minimization techniques, stall width requirements in most local parking codes are much larger than the widest SUVs.

Structured parking decks are one method to significantly reduce the overall parking footprint by minimizing surface parking. Figure 5-19 shows a parking deck used for a commercial development.

Shared parking in mixed-use areas and structured parking are techniques that can further reduce the conversion of land to impervious cover. A shared parking arrangement could include usage of the same parking lot by an office space that experiences peak parking demand during the weekday with a church that experiences parking demands during the weekends and evenings.

Figure 5-19. Structured Parking at an Office Park

Figure 5-20. Grass Paver Surface Used for Parking

Utilizing alternative surfaces such as porous pavers or porous concrete is an effective way to reduce the amount of runoff generated by parking lots. They can replace conventional asphalt or concrete in both new developments and redevelopment projects. Figure 5-20 is an example of porous pavers used at an overflow lot. Such pavers can also capture and treat runoff from other site areas. However, porous pavement surfaces generally require proper installation and more maintenance than conventional asphalt or concrete. For more specific information on using these alternative surfaces, see Section 4.3 of this manual.

Better Site Design Practice #14:
Reduce Setbacks and Frontages

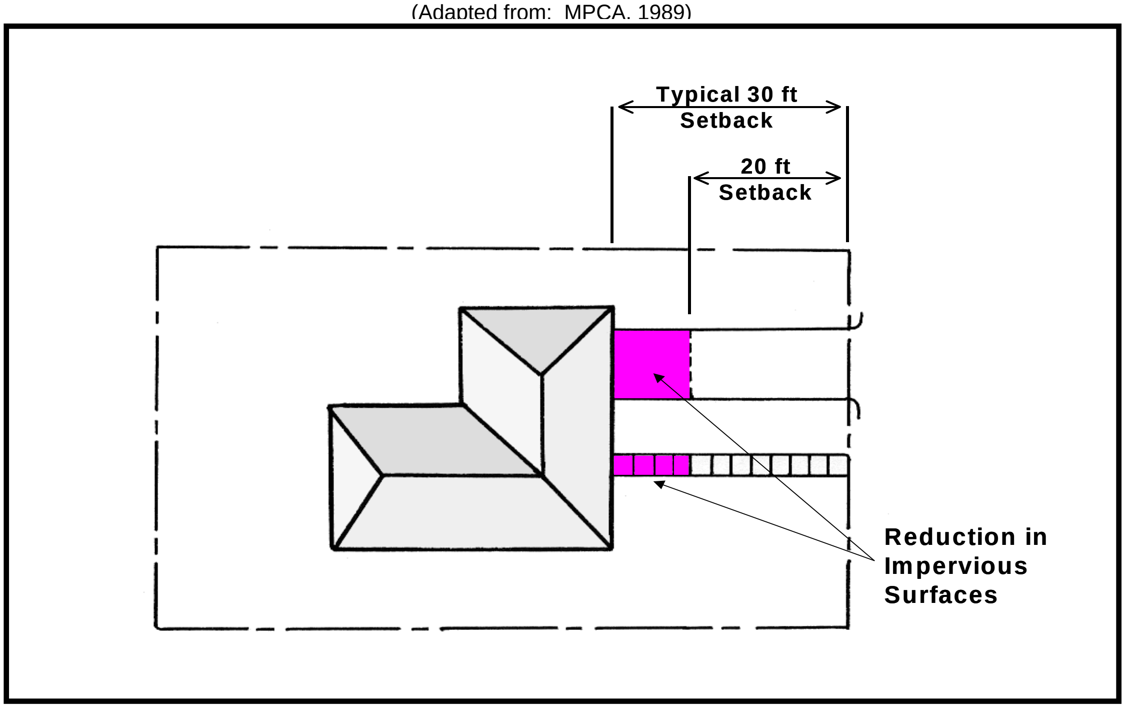
Reduction of Impervious Cover

Description: Use smaller front and side setbacks and narrower frontages to reduce total road length and driveway lengths.

KEY BENEFITS	USING THIS PRACTICE
• Reduces the amount of impervious cover and associated runoff and pollutants generated.	☑ Reduce building and home front and side setbacks. ☑ Consider narrower frontages.

Building and home setbacks should be shortened to reduce the amount of impervious cover from driveways and entry walks. A setback of 20 feet is more than sufficient to allow a car to park in a driveway without encroaching into the public right of way, and reduces driveway and walk pavement by more than 30 percent compared with a setback of 30 feet (see Figure 5-21).

Figure 5-21. Reduced Impervious Cover by Using Smaller Setbacks
(Adapted from: MPCA, 1989)

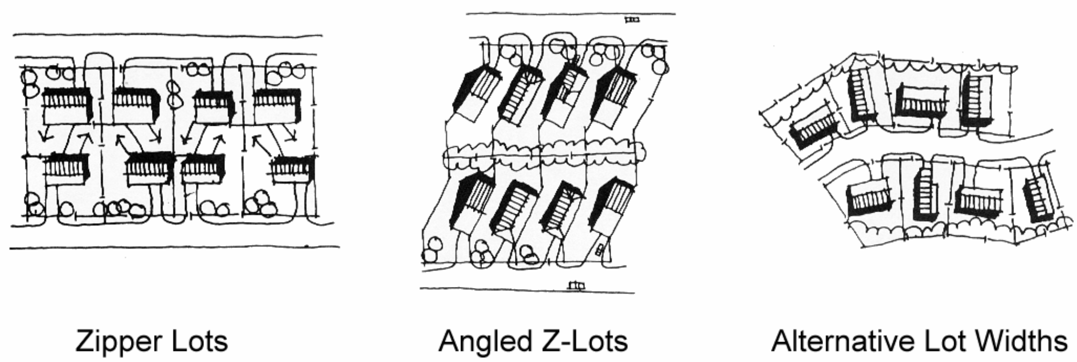


Further, reducing side yard setbacks and using narrower frontages can reduce total street length, which is especially important in cluster and open space designs. Figure 5-22 shows residential examples of reduced front and side yard setbacks and narrow frontages.

Flexible lot shapes and setback and frontage distances allow site designers to create attractive and unique lots that provide homeowners with enough space while allowing for the preservation of natural areas in a residential subdivision. Figure 5-23 illustrates various nontraditional lot designs.

Figure 5-22. Examples of Reduced Frontages and Side Yard Setbacks

Figure 5-23. Nontraditional Lot Designs
(Source: ULI, 1992)



Better Site Design Practice #15:
Use Fewer or Alternative Cul-de-Sacs

Reduction of Impervious Cover

Description: Minimize the number of residential street cul-de-sacs and incorporate landscaped areas to reduce their impervious cover. The radius of cul-de-sacs should be the minimum required to accommodate emergency and maintenance vehicles. Alternative turnarounds should also be considered.

KEY BENEFITS	USING THIS PRACTICE
• Reduces the amount of impervious cover and associated runoff and pollutants generated	☑ Consider alternative cul-de-sac designs

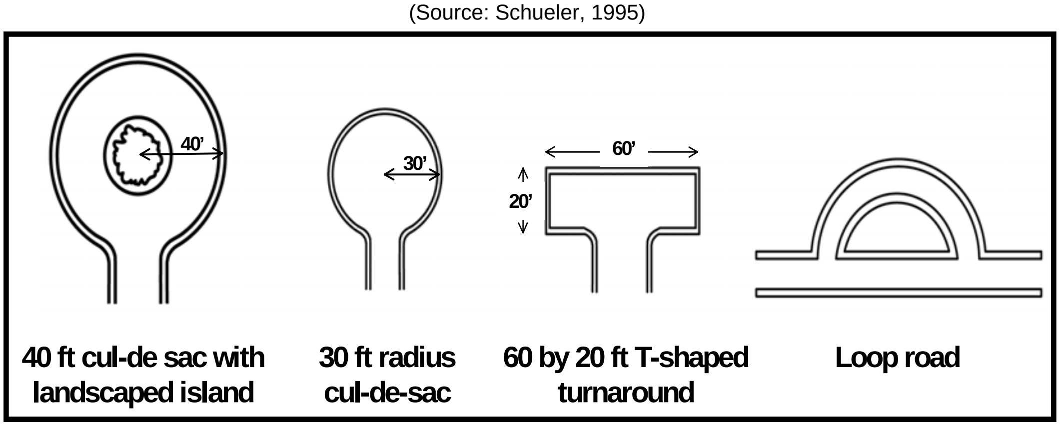
Alternative turnarounds are designs that replace cul-de-sacs and reduce the amount of impervious cover created in developments. Cul-de-sacs are local access streets with a closed circular end that allows for vehicle turnarounds. Many of these cul-de-sacs can have a radius of more than 40 feet. From a stormwater perspective, cul-de-sacs create a huge bulb of impervious cover, increasing the amount of runoff. For this reason, reducing the size of cul-de-sacs through the use of alternative turnarounds or eliminating them altogether can reduce the amount of impervious cover created at a site.

Numerous alternatives create less impervious cover than the traditional 40-foot cul-de-sac. These alternatives include reducing cul-de-sacs to a 30-foot radius and creating hammerheads, loop roads, and pervious islands in the cul-de-sac center (see Figure 5-24).

Sufficient turnaround area is a significant factor to consider in the design of cul-de-sacs. In particular, the types of vehicles entering into the cul-de-sac should be considered. Fire trucks, service vehicles and school buses are often cited as needing large turning radii. However, some fire trucks are designed for smaller turning radii. In addition, many newer large service vehicles are designed with a tri-axle (requiring a smaller turning radius) and many school buses usually do not enter individual cul-de-sacs.

Implementing alternative turnarounds will require addressing local regulations. Communities may have specific design criteria for cul-de-sacs and other alternative turnarounds that need to be modified.

Figure 5-24. Four Turnaround Options for Residential Streets
(Source: Schueler, 1995)



Better Site Design Practice #16:
Create Parking Lot Stormwater "Islands"

Reduction of Impervious Cover

Description: Provide stormwater treatment for parking lot runoff using bioretention areas, filter strips, and/or other practices that can be integrated into required landscaping areas and traffic islands.

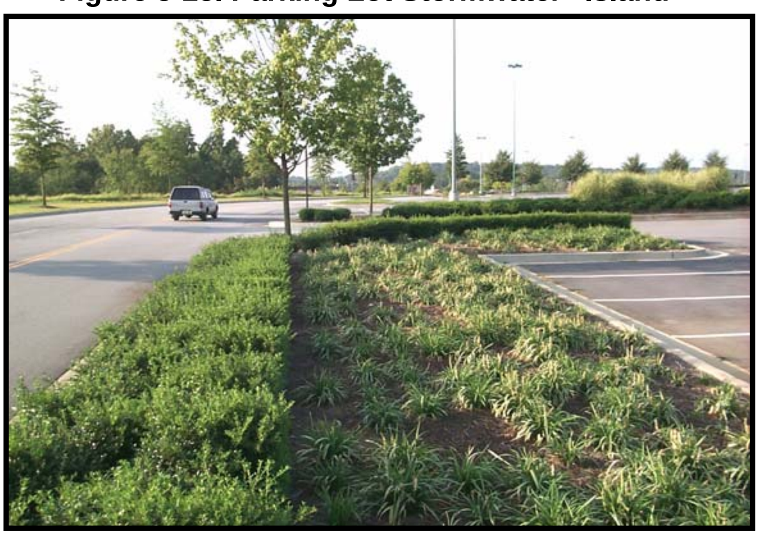
KEY BENEFITS	USING THIS PRACTICE
• Reduces the amount of impervious cover and associated runoff and pollutants generated. • Provides an opportunity for the siting of structural control facilities. • Trees in parking lots provide shading for cars and are more visually appealing.	☑ Integrate porous areas such as landscaped islands, swales, filter strips and bioretention areas in a parking lot design.

Parking lots should be designed with landscaped stormwater management "islands" which reduce the overall impervious cover of the lot as well as provide for runoff treatment and control in stormwater facilities.

When possible, expanses of parking should be broken up with landscaped islands which include shade trees and shrubs. Fewer large islands will sustain healthy trees better than more numerous very small islands. The most effective solutions in designing for tree roots in parking lots use a long planting strip at least 8 feet wide, constructed with sub-surface drainage and compaction resistant soil.

Structural control facilities such as filter strips, dry swales and bioretention areas can be incorporated into parking lot islands. Stormwater is directed into these landscaped areas and temporarily detained. The runoff then flows through or filters down through the bed of the facility and is infiltrated into the subsurface or collected for discharge into a stream or another stormwater facility. These facilities can be attractively integrated into landscaped areas and can be maintained by commercial landscaping firms. For detailed design specifications of filter strips, enhanced swales and bioretention areas, refer to Chapter 4. An example of a parking lot stormwater "island" is presented in Figure 5-25.

Figure 5-25. Parking Lot Stormwater "Island"



5.3.7 Using Natural Site Features for Stormwater Management

Traditional stormwater drainage design usually ignores and replaces natural drainage patterns, which often results in overly efficient hydraulic conveyance systems. These conveyance systems are overly efficient in that they quickly collect and carry water away from sites rather than allowing water to infiltrate naturally. Conveyance systems are composed of structural stormwater controls that are costly and often require high levels of maintenance to operate properly. The use of natural site features and drainage systems through careful site design can reduce the need and size of structural conveyance systems and controls.

Almost all sites contain natural features which can be used to help manage and mitigate runoff from development. Features on a development site might include natural drainage patterns, depressions, permeable soils, wetlands, floodplains, and undisturbed vegetated areas that can be used to reduce runoff, provide infiltration and stormwater filtering of pollutants and sediment, recycle nutrients, and maximize on-site storage of stormwater. Site design should seek to utilize the natural and/or nonstructural drainage system and improve the effectiveness of natural systems rather than to ignore or replace them. These natural systems typically require low or no maintenance and will continue to function many years into the future.

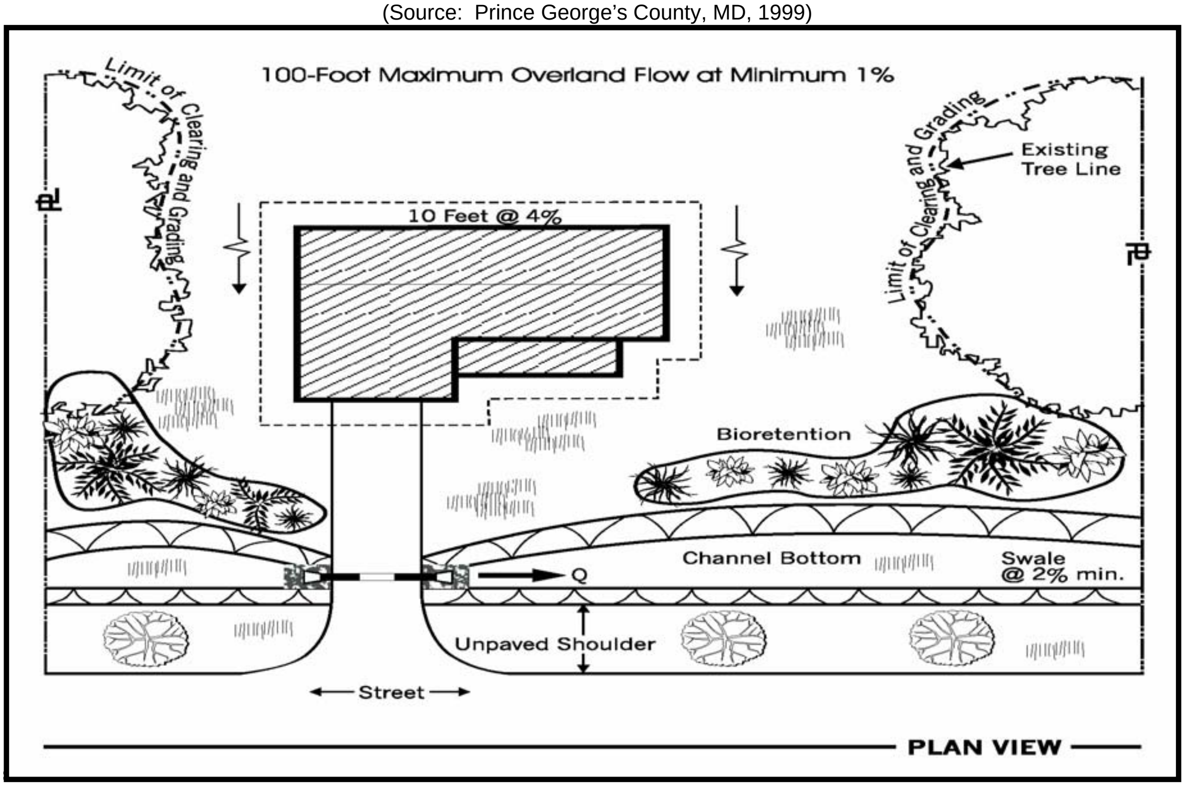
Some of the methods of incorporating natural features into an overall stormwater management site plan include the following practices:

17. Use Buffers and Undisturbed Areas
18. Use Natural Drainageways Instead of Storm Sewers
19. Use Vegetated Swales Instead of Curb and Gutter
20. Drain Runoff to Pervious Areas

Figure 5-26 presents an example of these better site design practices on a residential lot. The following pages cover each practice in more detail.

Figure 5-26. Residential Site Design Using Natural Features for Stormwater Management

(Source: Prince George's County, MD, 1999)



Better Site Design Practice #17:
Use Buffers and Undisturbed Areas

Utilization of Natural Features for Stormwater Management

Description: Undisturbed natural areas such as forested preservation areas and stream buffers can be used to treat and control stormwater runoff from other areas of the site with proper design.

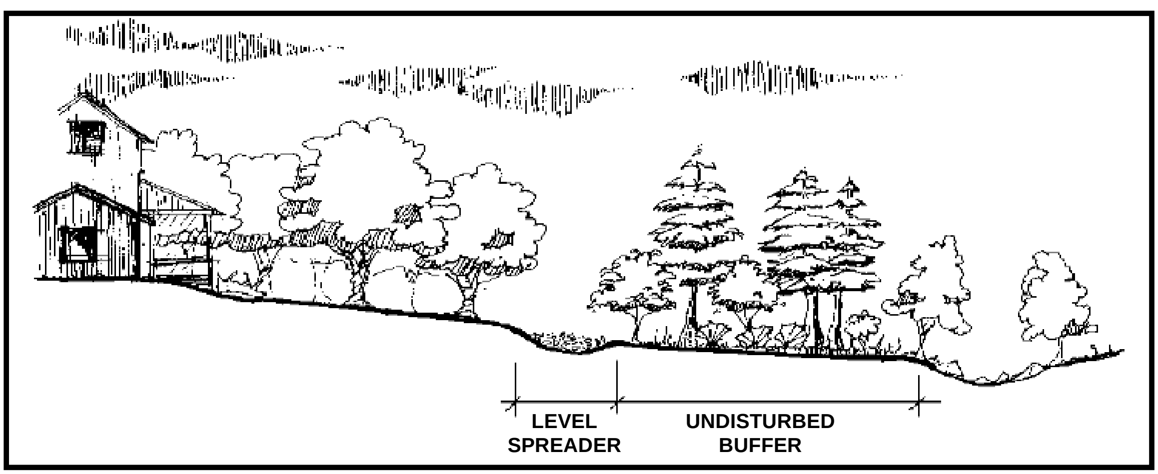
KEY BENEFITS	USING THIS PRACTICE
• Riparian buffers and undisturbed vegetated areas can be used to filter and infiltrate stormwater runoff • Natural depressions can provide inexpensive storage and detention of stormwater flows • A stormwater site design reduction can be taken the areas comply with the criteria listed in Section 5.2	☑ Direct runoff towards buffers and undisturbed areas using a level spreader to ensure sheet flow ☑ Utilize natural depressions for runoff storage

Runoff can be directed towards riparian buffers and other undisturbed natural areas delineated in the initial stages of site planning to infiltrate runoff, reduce runoff velocity and remove pollutants. Natural depressions can be used to temporarily store (detain) and infiltrate water, particularly in areas with porous (hydrologic soil group A and B) soils.

The objective of using natural areas for stormwater infiltration is to intercept runoff before it has become substantially concentrated and then distribute this flow evenly (as sheet flow) to the buffer or natural area. This can typically be accomplished using a level spreader, as seen in Figure 5-27. A mechanism for the bypass of higher flow events should be provided to reduce erosion or damage to a buffer or undisturbed natural area.

Carefully constructed berms can be placed around natural depressions and below undisturbed vegetated areas with porous soils to provide for additional runoff storage and/or infiltration of flows.

Figure 5-27. Use of a Level Spreader with a Riparian Buffer
(Adapted from NCDENR, 1998)



Better Site Design Practice #18:

Use Natural Drainageways Instead of Storm Sewers

Utilization of Natural Features for Stormwater Management

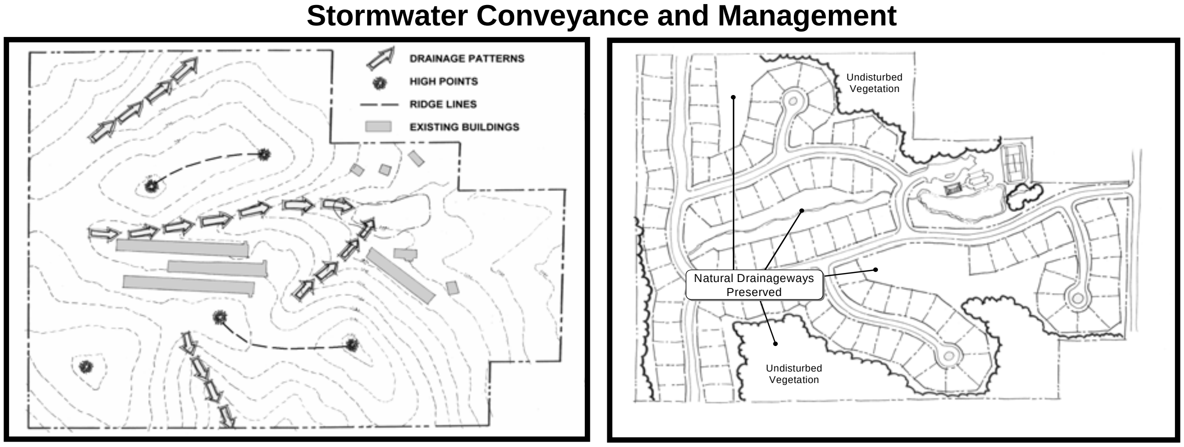
Description: The natural drainage paths of a site can be used instead of constructed underground storm sewers or concrete open channels.

KEY BENEFITS	USING THIS PRACTICE
• Use of natural drainageways reduces the cost of constructing storm sewers or other conveyances, and may reduce the need for land disturbance and grading. • Natural drainage paths are less hydraulically efficient than man-made conveyances, resulting in longer travel times and lower peak discharges. • Can be combined with buffer systems to allow for stormwater filtration and infiltration.	☑ Preserve natural flow paths in the site design ☑ Direct runoff to natural drainageways, ensuring that peak flows and velocities will not cause channel erosion

Structural drainage systems and storm sewers are designed to be hydraulically efficient in removing stormwater from a site. This type of system tends to increase peak runoff discharges, flow velocities, and pollutant loading to downstream waters. Alternatives are natural drainageways and vegetated swales (where slopes and soils permit), which carry stormwater flows to their natural outlets, particularly for low-density development and residential subdivisions.

The use of natural open channels allows for more storage of stormwater flows on-site, lower stormwater peak flows, a reduction in erosive runoff velocities, infiltration of a portion of the runoff volume, and the capture and treatment of stormwater pollutants. It is critical that natural drainageways be protected from higher post-development flows by applying downstream channel protection methods (including the CPv criteria) to prevent erosion and degradation. Figure 5-28 presents an example of the use of natural drainageways for stormwater conveyance.

Figure 5-28. Example of the Use of Natural Drainageways for Stormwater Conveyance and Management



Better Site Design Practice #19:
Use Vegetated Swales Instead of Curb and Gutter

Utilization of Natural Features for Stormwater Management

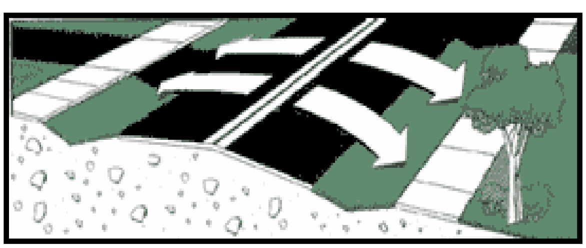
Description: Where density, topography, soils, slope, and safety concerns permit, vegetated open channels can be used in the street right-of-way to convey and treat stormwater runoff from roadways.

KEY BENEFITS	USING THIS PRACTICE
• Reduces the cost of road and storm sewer construction • Provides for some runoff storage and infiltration, as well as treatment of stormwater • A stormwater site design reduction can be taken if the swales comply with the criteria listed in section 5-2	☑ Use vegetated open channels (enhanced wet or dry swales or grass channels) in place of curb and gutter to convey and treat stormwater runoff

Curb and gutter storm drain systems allow for the quick transport of stormwater, which results in increased peak flow and flood volumes and reduced runoff infiltration. Curb and gutter systems also do not provide treatment for stormwater that has been polluted from vehicle emissions, pet waste, lawn runoff, and litter.

Open vegetated channels along a roadway (see Figure 5-31) remove pollutants by allowing infiltration and filtering to occur, unlike curb and gutter systems which move water with virtually no treatment. Engineering advances prevent past problems with roadside ditches, which suffered from erosion, standing water and break up at the road edge. Grass channels and enhanced dry swales are two such alternatives. If they are properly installed under the right site conditions, they are excellent methods for treating stormwater on-site. In addition, open vegetated channels can be less expensive to install than curb and gutter systems. Further design information and specifications for grass channels and enhanced swales can be found in Chapter 4 of this manual.

Figure 5-29. Vegetated Swales Instead of Curb and Gutter



Better Site Design Practice #20:
Drain Runoff to Pervious Areas

Utilization of Natural Features for Stormwater Management

Description: Where possible, direct runoff from impervious areas such as rooftops, roadways and parking lots to pervious areas, open channels or vegetated areas to provide for water quality treatment and infiltration. Avoid routing runoff directly to the structural stormwater conveyance system.

KEY BENEFITS	USING THIS PRACTICE
• Sending runoff to pervious vegetated areas increases overland flow time and reduces peak flows • Vegetated areas can often filter and infiltrate stormwater runoff • A stormwater site design reduction can be taken if the area complies with the criteria listed in Section 5-2.	☑ Minimize directly connected impervious areas and drain runoff as sheet flow to pervious vegetated areas

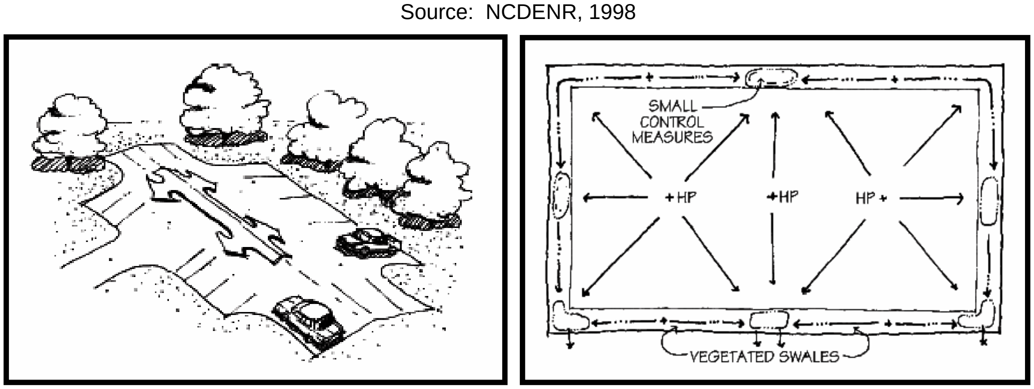
Stormwater quantity and quality benefits can be achieved by routing the runoff from impervious areas to pervious areas such as lawns, landscaping, filter strips and vegetated channels. Much like the use of undisturbed buffers and natural areas (Better Site Design Practice #17), revegetated areas such as lawns and engineered filter strips and vegetated channels can act as biofilters for stormwater runoff and provide for infiltration in porous (hydrologic group A and B) soils. In this way, the runoff is “disconnected” from a hydraulically efficient structural conveyance such as a curb and gutter or storm drain system.

Some of the methods for disconnecting impervious areas include:

- Designing roof drains to flow to vegetated areas
- Directing flow from paved areas such as driveways to stabilized vegetated areas
- Breaking up flow directions from large paved surfaces (see Figure 5-30).
- Carefully locating impervious areas and grading landscaped areas to achieve sheet flow runoff to the vegetated pervious areas

For maximum benefit, runoff from impervious areas to vegetated areas must occur as sheet flow and vegetation must be stabilized. See Chapters 3 and 7 for more design information and specifications on filter strips and vegetated channels.

Figure 5-30. Design Paved Surfaces to Disperse Flow to Vegetated Areas
Source: NCDENR, 1998



5.3.8 Better Site Design Examples (Source: ARC, 2001)

Residential Subdivision Example 1
A typical residential subdivision design on a parcel is shown in Figure 5-31(a). The entire parcel except for the subdivision amenity area (clubhouse and tennis courts) is used for lots. The entire site is cleared and mass graded, and no attempt is made to fit the road layout to the existing topography. Because of the clearing and grading, all of the existing tree cover and vegetation and topsoil are removed, dramatically altering both the natural hydrology and drainage of the site. The wide residential streets create unnecessary impervious cover and a curb and gutter system that carries stormwater flows to the storm sewer system. No provision for nonstructural stormwater treatment is provided on the subdivision site.

A residential subdivision employing stormwater better site design practices is presented in Figure 5-31(b). This subdivision configuration preserves a quarter of the property as undisturbed open space and vegetation. The road layout is designed to fit the topography of the parcel, following the high points and ridgelines. The natural drainage patterns of the site are preserved and are utilized to provide natural stormwater treatment and conveyance. Narrower streets reduce impervious cover and grass channels provide for treatment and conveyance of roadway and driveway runoff. Landscaped islands at the ends of cul-de-sacs also reduce impervious cover and provide stormwater treatment functions. When constructing and building homes, only the building envelopes of the individual lots are cleared and graded.

Residential Subdivision Example 2
Another typical residential subdivision design is shown in Figure 5-32(a). Most of this site is cleared and mass graded, with the exception of a small riparian buffer along the large stream at the right boundary of the property. Almost no buffer was provided along the small stream that runs through the middle of the property. In fact, areas within the 100-year floodplain were cleared and filled for home sites. As is typical in many subdivision designs, this one has wide streets that can be used for on-street parking and large cul-de-sacs.

The better site design subdivision can be seen in Figure 5-32(b). This subdivision layout was designed to conform to the natural terrain. The street pattern consists of a wider main thoroughfare that winds through the subdivision along the ridgeline. Narrower loop roads branch off of the main road and utilize landscaped islands. Large riparian buffers are preserved along both the small and large streams. The total undisturbed conservation area is close to one-third of the site.

Commercial Development Example
Figure 4-33(a) shows a typical commercial development containing a supermarket, drugstore, smaller shops and a restaurant on an out-lot. The majority of the parcel is a concentrated parking lot area. The only pervious area is a small replanted vegetation area acting as a buffer between the shopping center and adjacent land uses. Stormwater quality and quantity control are provided by a wet extended detention basin in the corner of the parcel.

A better site design commercial development can be seen in Figure 5-33(b). Here the retail buildings are dispersed on the property, providing more of an “urban village” feel with pedestrian access between the buildings. The parking is broken up, and bioretention areas for stormwater treatment are built into parking lot islands. A large bioretention area, which serves as open green space, is located at the main entrance to the shopping center. A larger undisturbed buffer has been preserved on the site. Because the bioretention areas and buffer provide water quality treatment, only a dry extended detention basin is needed for water quantity control.

Office Park Example
An office park with a conventional design is shown in Figure 5-34(a). Here the site has been graded to fit the building layout and parking area. All of the vegetated areas of this site are replanted areas. The better site design layout, presented in Figure 5-34(b), preserves undisturbed vegetated buffers and open space areas on the site. The layout has been designed to fit the natural terrain of the site. A modular porous paver system is used for the overflow parking areas.

Figure 5-31(a). Example 1 Traditional Residential Subdivision Design

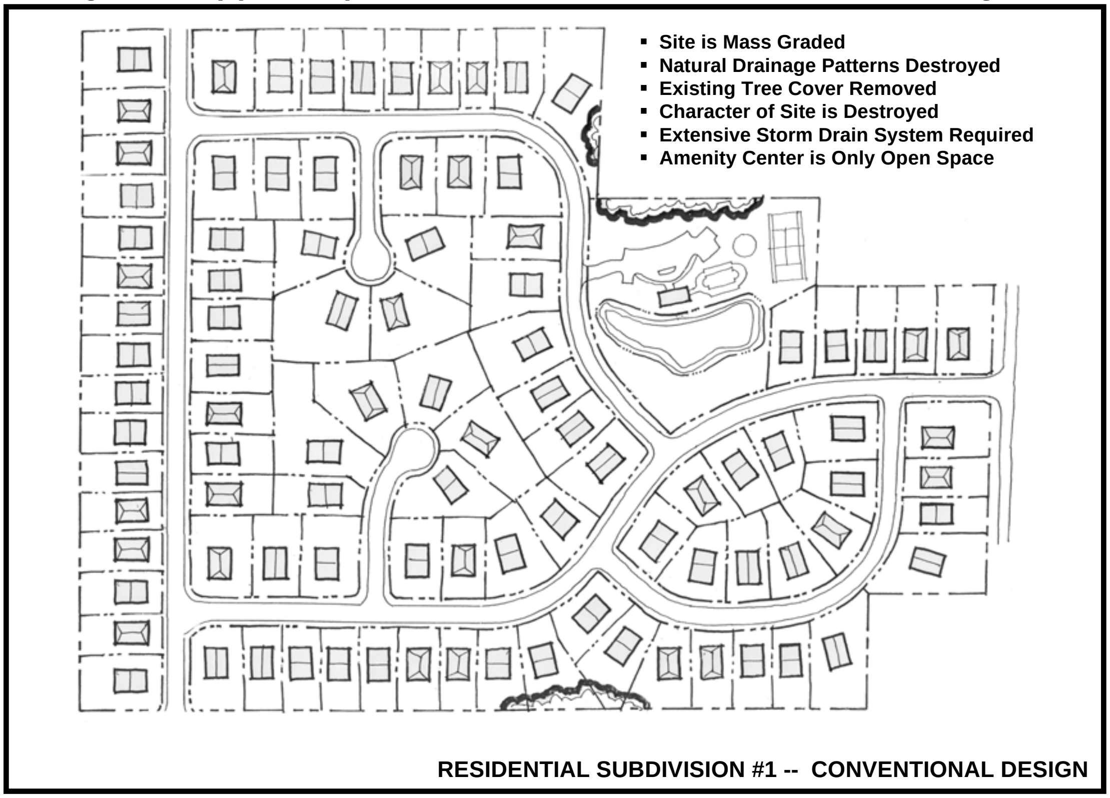


Figure 5-31(b). Example 1 Residential Subdivision Design after Application of Better Site Design Practices

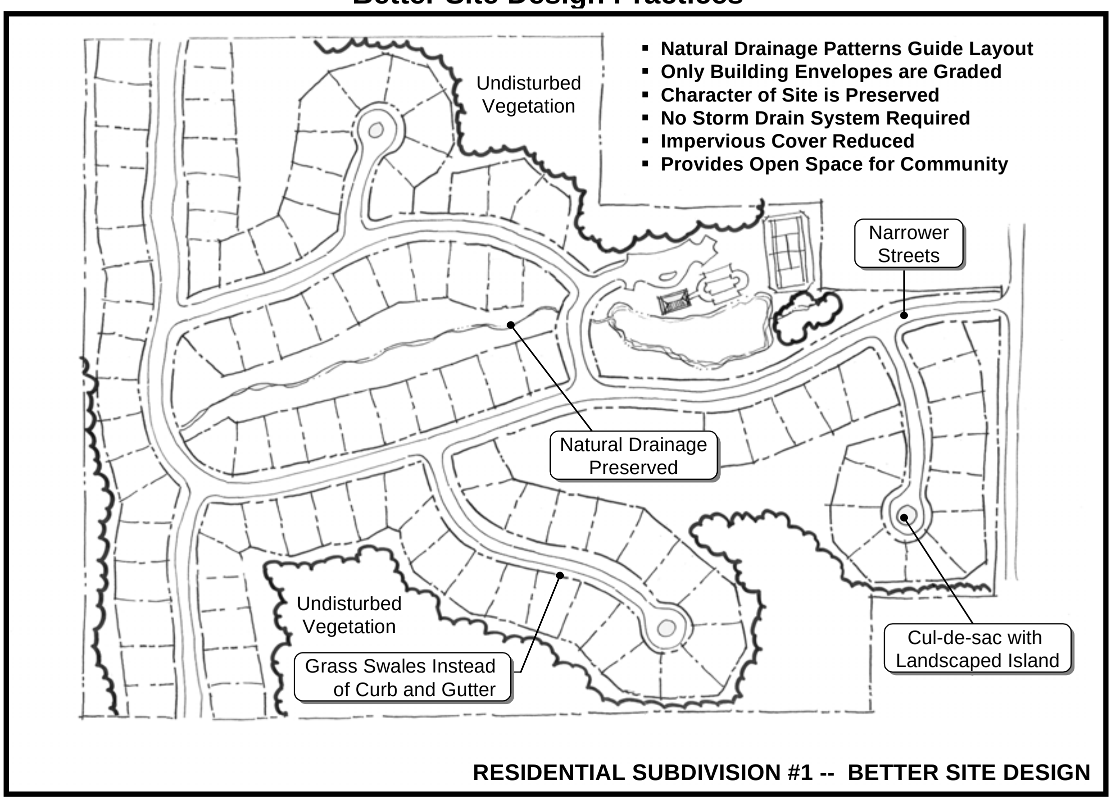


Figure 5-32(a). Example 2 Traditional Residential Subdivision Design

Figure 5-32(b). Example 2 Residential Subdivision Design after Application of Better Site Design Practices

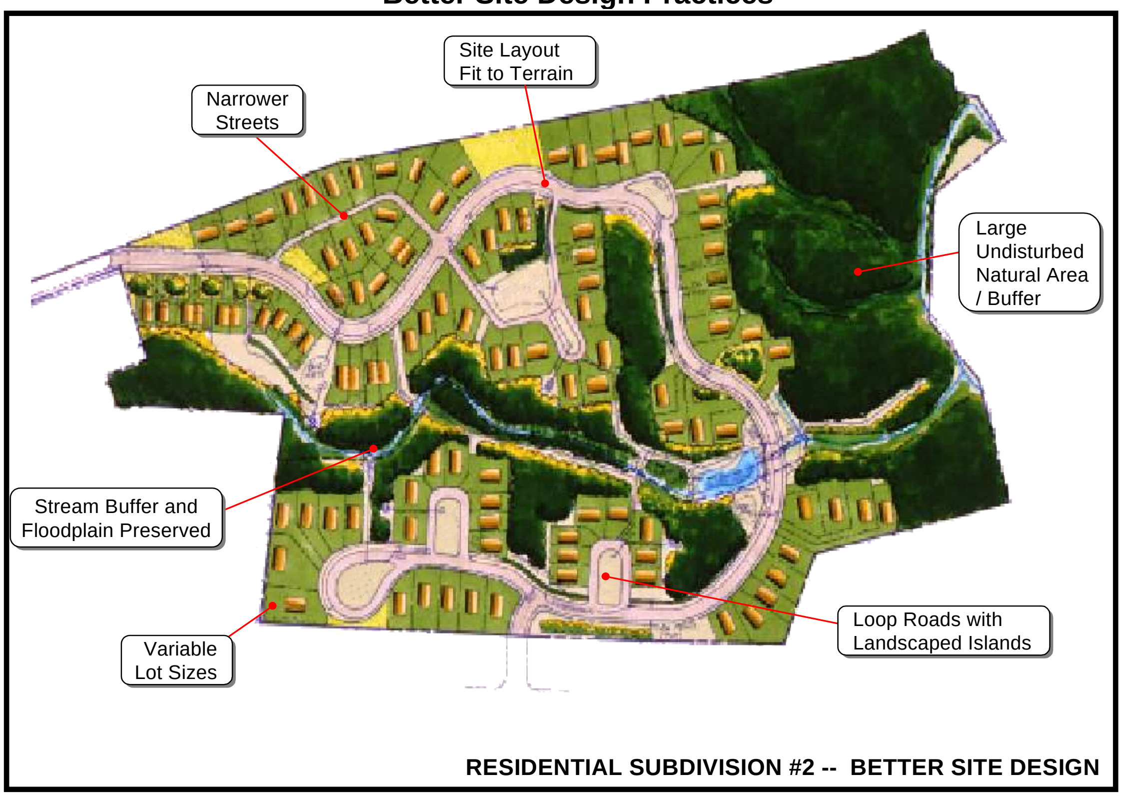


Figure 5-33(a). Example 3 Traditional Commercial Development Design

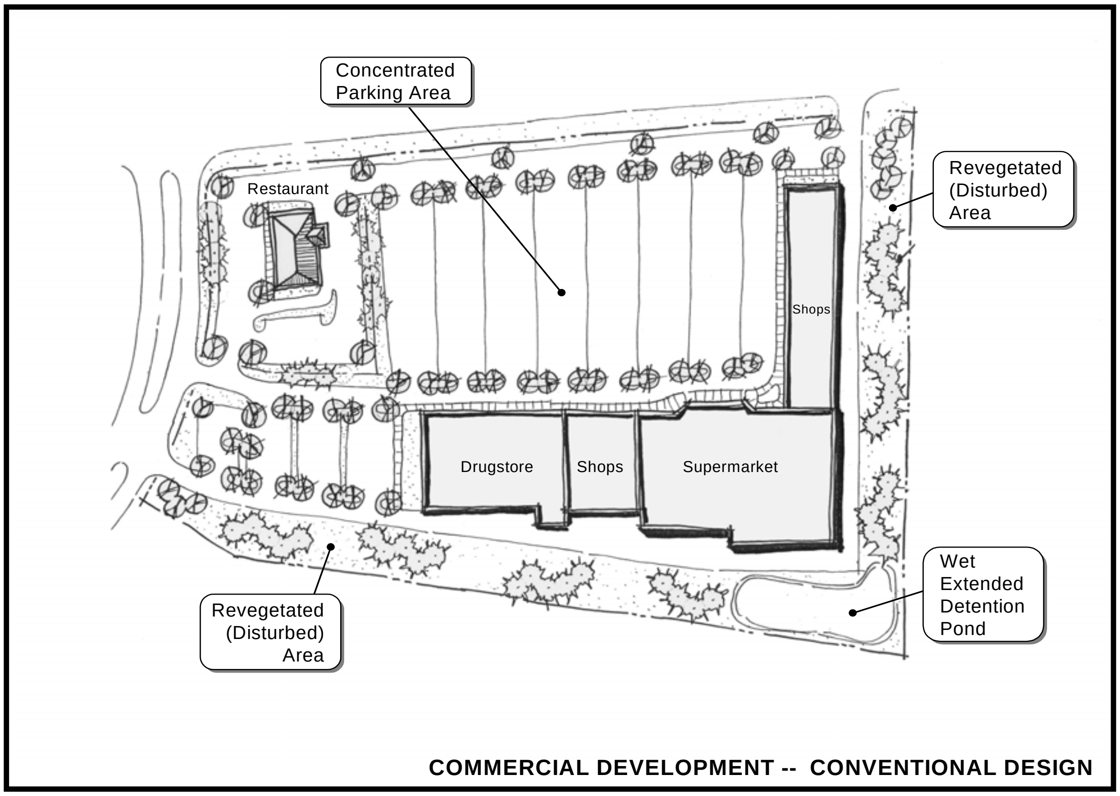


Figure 5-33(b). Example 3 Commercial Development Design after Application of Better Site Design Practices

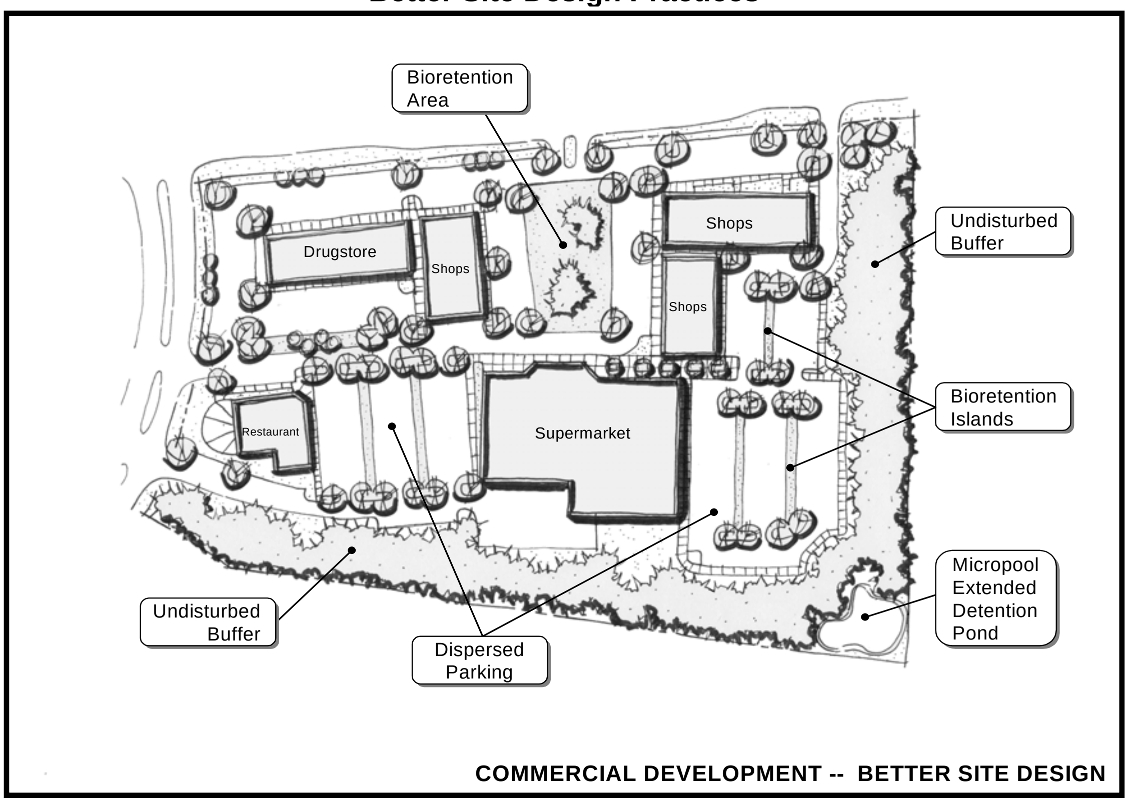
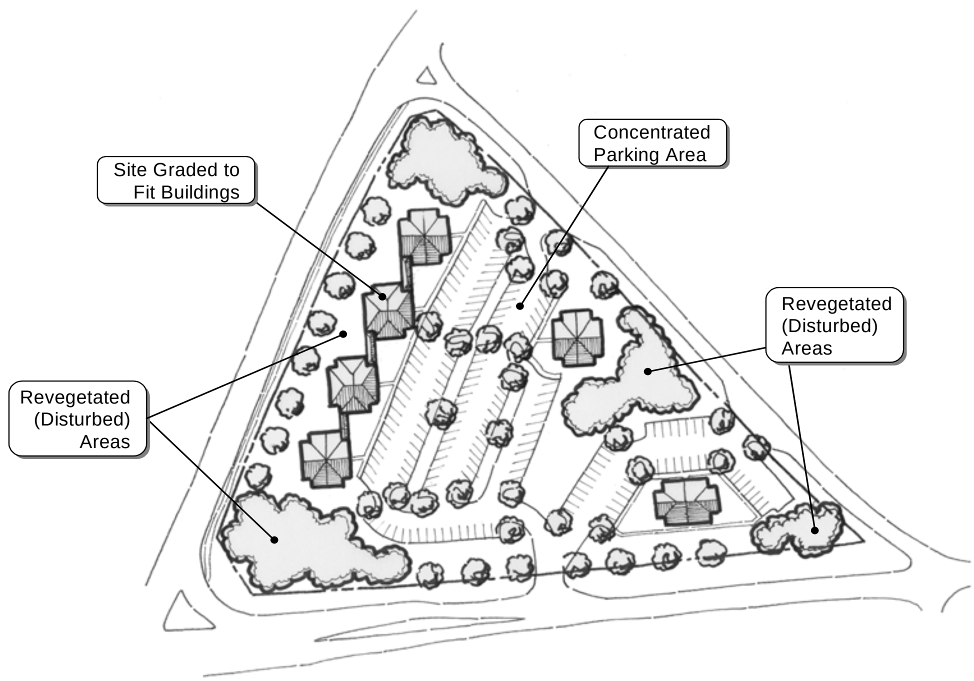
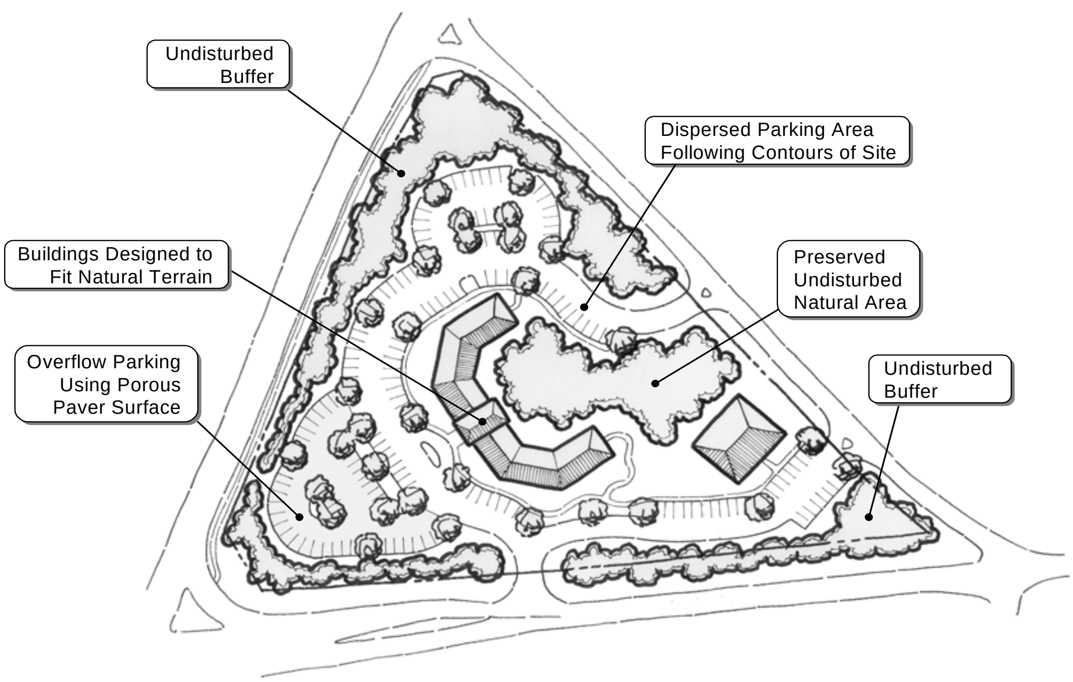


Figure 5-34(a). Example 4 Traditional Office Park Development



OFFICE PARK -- CONVENTIONAL DESIGN

Figure 5-34(b). Example 4 Office Park Development after Application of Better Site Design Practices



OFFICE PARK -- BETTER SITE DESIGN

5.4 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 1 Stormwater Policy Guidebook.* 2001.

Knox County, Tennessee. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

Minnesota Pollution Control Agency (MPCA). *Protecting Water Quality in Urban Areas*. 1989.

North Carolina Department of Environment and Natural Resources (NCDENR). *Stormwater Management Site Planning*. 1998

Prince George's County, MD. *Low-Impact Development Design Strategies, An Integrated Design Approach*. 1999

Schueler, T. *Site Planning for Urban Stream Protection*. Prepared by Center for Watershed Protection (CWP). Metropolitan Washington Council of Governments, 1995.

Sykes, R.D. *Chapter 31 – Site Planning*. University of Minnesota. 1989

Urban Land Institute. *Density by Design*. 1992.

Virginia Polytechnic Institute and State University (VPISU), College of Architecture and Urban Studies. *Water Sensitive Site Planning*. 2000.

www.stormwatercenter.net Better Site Design: Green Parking. Accessed August 2006.

Table of Contents

CHAPTER 6 — VEGETATED BUFFERS

Chapter 6 – List of Figures

Chapter 6 – List of Tables

This page left intentionally blank

CHAPTER

6

VEGETATED BUFFERS

6.1 Introduction

The purpose of this section is to define requirements for vegetated buffers and to enable cities that use this manual to comply with the requirements of the State of Tennessee's NPDES MS4 permit. In this manual, a vegetated buffer is defined as:

> *A use-restricted vegetated area of existing vegetation, or enhanced or restored vegetation, that is located along the perimeter of streams, ponds, lakes or wetlands, containing natural vegetation and grasses.*

The intent of the vegetated buffers required by this manual is to provide a vegetation anchor for streambanks, pond and lake shorelines and wetland boundaries, thus decreasing sediment loads that originate from eroding banks, and to provide canopy to shade streams, protecting them from thermal impacts. Buffers that are wider than the minimum width required by this manual are able to provide other, greater benefits to streams and other waterbodies such as protection from pollutants carried in stormwater runoff, providing habitat for wildlife, providing areas for runoff control and flood storage. Therefore, incentives to expand buffer widths and vegetation schemes in order to increase the functions provided by the buffers and heighten the overall water quality and flood benefits are provided in this chapter and in Chapter 5.

The policies that are stated in sections 6.2 and 6.3 shall be considered the minimum requirements to comply with the local ordinance that contains the vegetated buffer requirement.

6.2 Minimum Requirements

6.2.1 General

The following requirements shall apply to all vegetated buffers.

1. The local jurisdiction may invoke more stringent requirements for vegetated buffers than the minimum standards stated in this chapter for streams designated by the State of Tennessee as impaired or high quality waters, to comply with a State or Federal permit or a Total Maximum Daily Load (TMDL), in areas identified by the local jurisdiction as "hotspot areas", or if the land adjacent to the buffer includes any of the uses or activities listed below:
    b) Drainfields from on-site sewage disposal and treatment system (i.e., a septic system), subsurface discharges from a wastewater treatment plant, or land application of biosolids or animal waste.

    c) The storage of hazardous substances or petroleum facilities.

    d) Raised septic systems or animal feedlot operations.

    e) Solid waste landfills, junkyards, or other areas identified by the local jurisdiction as pollutant hotspots.
2. The vegetated buffer shall be managed and maintained to protect the intended functions of the buffer as stated in this chapter.
3. Stormwater runoff that is intended for discharge to the vegetated buffer shall be discharged as

sheet flow. In order to claim the stream and vegetated buffers WQv reduction, a level spreader must be used to distribute all channelized flow that enters the buffer into sheet flow prior to discharging into the buffer area. The level spreader must be effective for the 1-year 24-hour water quality design storm; flows from storms larger than this value can bypass the level spreader in channels or pipes. Water that has already been treated to meet the 80% TSS removal standard can bypass the buffer in a pipe or channel. The local jurisdiction will provide guidance on design of outlets that will remain stable and not cause channel erosion. More information on level spreaders can be found in section 6.3.

4. A vegetated buffer area shall be placed into a permanent water quality easement that is recorded with the deed to the parcel and held by the local jurisdiction where the buffer is located.
5. Vegetated buffer areas shall be maintained through the declaration of a protective covenant, which must be approved and shall be enforceable by the local jurisdiction where the buffer is located. The covenant shall be recorded with the deed and shall run with the land and continue in perpetuity.
6. The vegetated buffer shall be use- and disturbance-restricted, and kept free from clearing, grading, filling, waste dumping, paving and building activities of nearby site development in accordance with the requirements stated in this chapter.
7. All areas of the vegetated buffer, including streambanks, shall be left in a stabilized condition upon completion of construction, restoration, enhancement or maintenance activities. No actively eroding, bare or unstable areas shall remain, unless approved by the local jurisdiction. No actively eroding, bare, or unstable vertical stream banks shall remain unless the Tennessee Department of Environment and Conservation (TDEC) has determined there is no better alternative. Placement of riprap and other hard armor is only allowed when it has been shown by the property owner that vegetative alternatives, such as bioengineered stabilization, are not feasible.
8. The property owner is responsible for obtaining all required State and Federal permits prior to performing work in and around Waters of the State.
9. Permanent boundary markers, in the form of signage approved or provided by the local jurisdiction where the buffer is located may be required to mark the limits of the vegetated buffer. The developer or property owner should contact the local jurisdiction to determine if boundary markers are required. If so, such markers shall be installed prior to recording of the final plat, and the issuance of a Certificate of Occupancy. Permanent boundary markers that have been removed or destroyed must be replaced.
10. The property owner is responsible for the maintenance and perpetual protection of the buffer area.
11. The State of Tennessee requires vegetated buffers during construction activities via provisions contained in the Tennessee Construction General Permit (CGP) or other regulatory permits and processes. The State's requirements may, or may not, align with the policies stated in this chapter. The developer or property owner should check with the local jurisdiction to determine if there are conflicts with any State or Federal buffer requirements.

6.2.2 Applicability

Vegetated buffers are required for all new developments and redevelopments that must submit a Water Quality Management Plan. In general, buffers are not required:

- around the perimeter of ponds that have no known connection to streams, other ponds, lakes or wetlands; or,

- for BMPs that are designed, constructed and maintained for the purposes of stormwater quality and/or quantity control, unless expressly required by the design standards and criteria for the facility that are provided in this manual. However, designed vegetated filter strips that are constructed per the requirements stated in Chapter 4 of this manual can be considered as a pre-treatment measure for stormwater runoff entering such facilities.

6.2.3 Width

Vegetated buffers shall have a minimum width of twenty-five (25) feet. The local jurisdiction may require a wider width for buffers in accordance with policy #1 listed in section 6.1 of this chapter. Properly designed and managed buffers of fifty-feet (50) feet or greater width may qualify for a WQv reduction and TSS removal of 80%. The stream and vegetated buffer reduction is discussed in Section 5.2.5.

The width of the vegetated buffer shall be measured in the following manner:

- For streams, the buffer shall be measured perpendicular from the top-of-bank of the active channel. For those streams that do not have a clearly defined top-of-bank, the buffer shall be measured perpendicular from the centerline of the stream. Examples of these measurements are shown in Figures 6-1a and 6-1b.
- For wetlands, the buffer shall be as measured from the outermost edge of the wetland as determined by USACE, NRCS, or TDEC.
- For ponds and lakes, the buffer shall be measured perpendicular landward from the topographic contour that defines the normal pool elevation, as shown in Figure 6-2.

Figure 6-1a. Example Buffer Width Measurement – Top-of-Bank

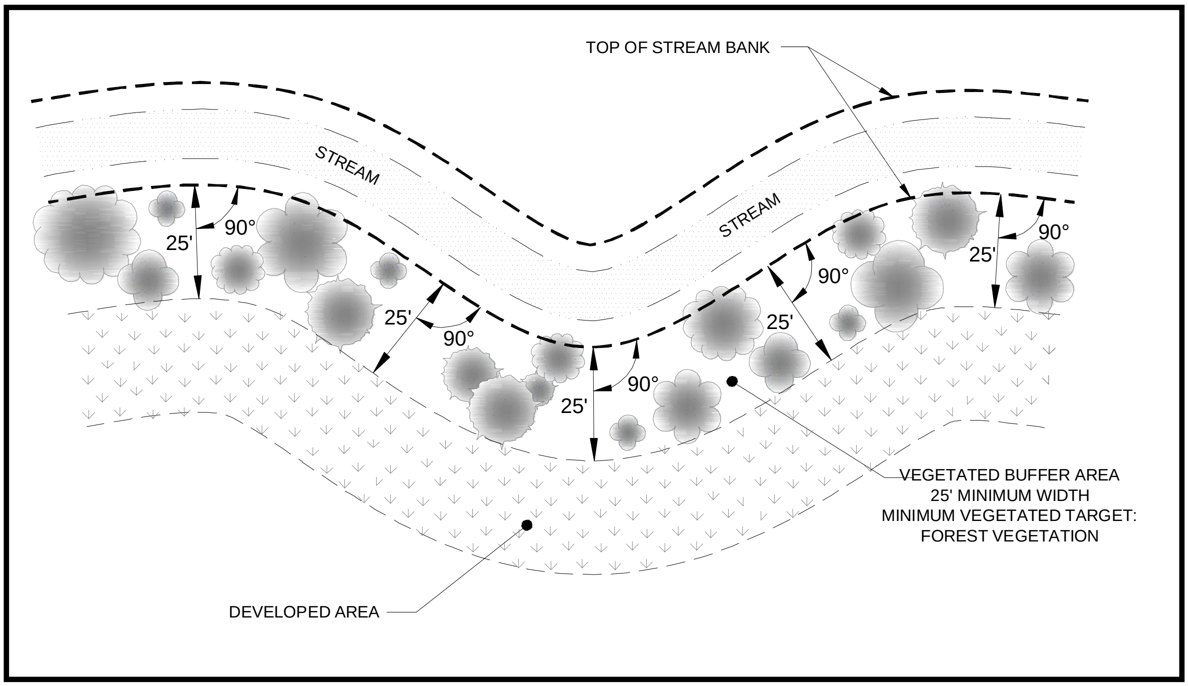


Figure 6-1b. Example Buffer Width Measurement – Stream Centerline

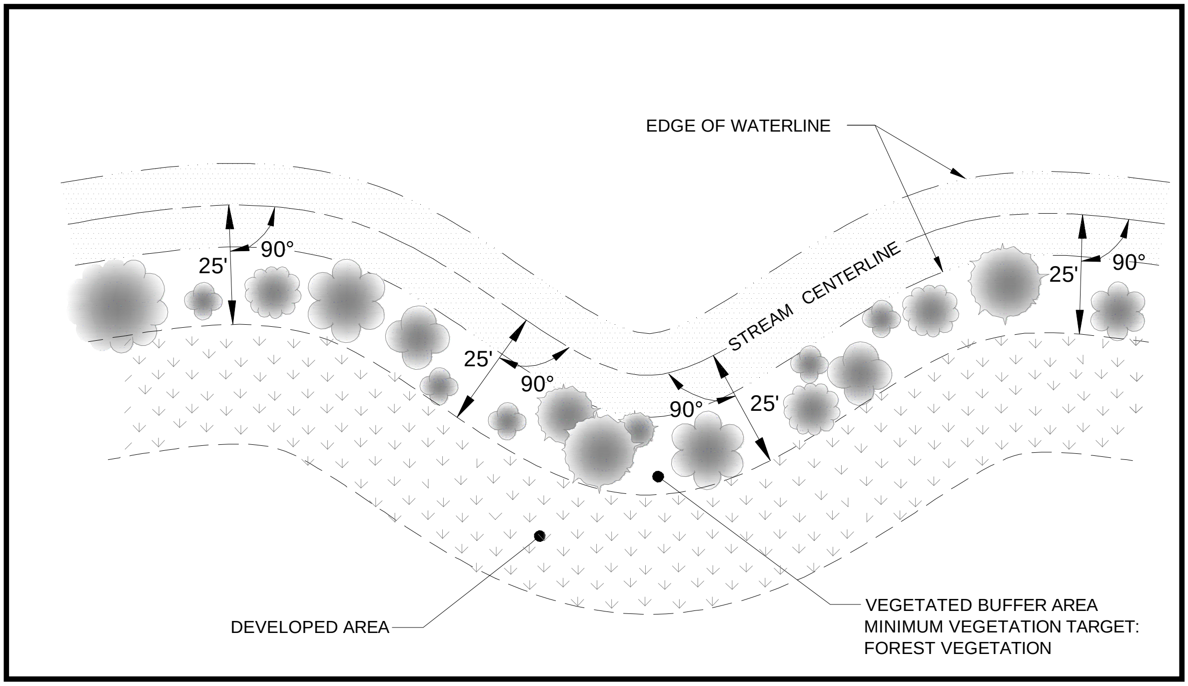
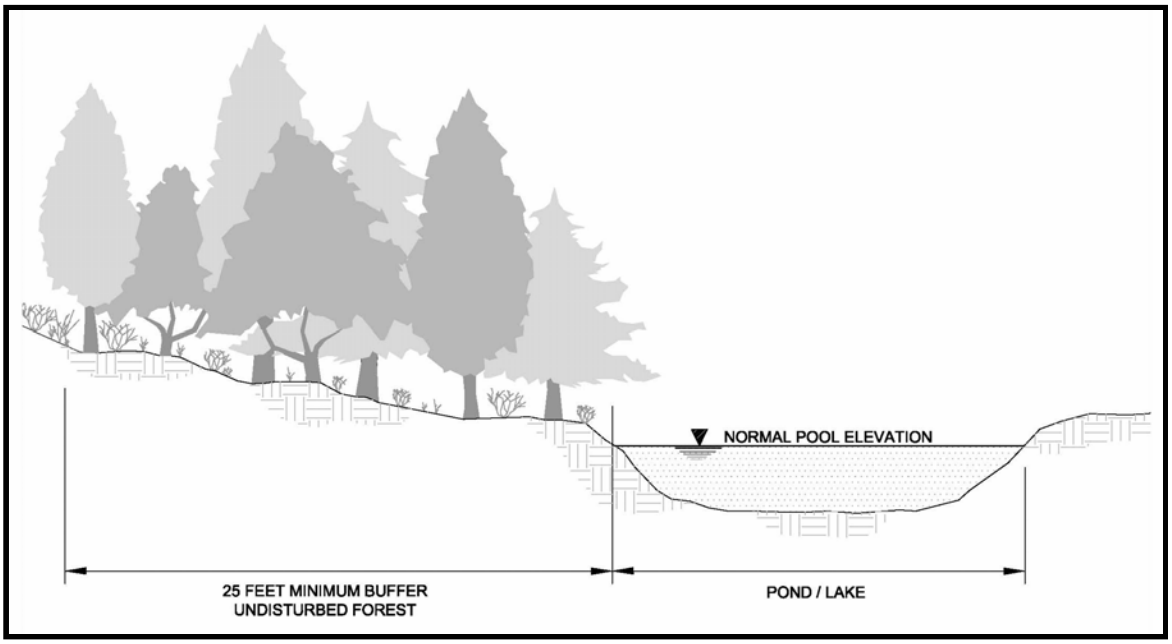


Figure 6-2. Example Buffer Width Measurement – Normal Pool Elevation



6.2.4 Vegetation

6.2.4.1 Minimum Requirements

The following minimum requirements shall apply to all vegetated buffer areas.

1. The minimum target vegetative cover for vegetated buffers located along streams and around wetlands shall be moderately dense forest with native, non-invasive trees and understory

vegetation that provides ground coverage over one-hundred percent (100%) of the buffer area. Understory vegetation must consist of native woody shrubs or dense grasses or a grass/shrub combination. Along streams, trees and other woody vegetation must exist at a density suitable to provide shade for the stream and stabilize stream banks. If the vegetated buffer area can be characterized as an early successional forest at the time of development, consisting of a combination of grasses, vines, shrubs, trees or tree saplings that has the potential to meet the vegetative target upon maturation, vegetative restoration or enhancement of the buffer area (see #6 below) will not be required provided that the vegetation appears healthy, provides adequate ground coverage, and consists largely of native and non-invasive species.

2. The minimum target vegetative cover for buffers located around ponds and lakes shall be dense, native grasses that provide vegetative cover for one-hundred percent (100%) of the buffer area.

3. Increased use of trees, shrubs and understory vegetation beyond the minimum requirements stated in this section is strongly encouraged to promote infiltration and filtration of stormwater runoff. For maximum benefit to the buffered waterbody, the vegetated buffer area should remain undisturbed and be planted entirely with native vegetation, which will minimize or eliminate the need for vegetative maintenance. Additional information on water quality benefits and incentives to go beyond these minimum requirements is provided in section 6.4.

4. Bare spots, areas of erosion, or landscaped areas that contain mulch, rock, or other landscaping materials are prohibited within the vegetated buffer area.

5. Impervious materials are prohibited within the vegetated buffer area, except those associated with the approved uses defined in section 6.2.5 below.

6. Vegetative restoration or enhancement of the buffer area may be required if:

    a) construction or significant vegetation maintenance is planned in the vegetated buffer area;

    b) streambank instability or erosion is evident in the area of the buffer;

    c) the vegetation that exists in the buffer area at the time of development or redevelopment of the property does not conform to the vegetative requirements stated in this section, or does not meet the intent of the buffer (i.e., to stabilize streambanks or provide shade) but could reasonably provide these benefits if restoration occurred;

    d) the buffer area has significant populations of non-native and/or invasive plan species; or,

    e) the buffer area has significant areas of unhealthy, damaged, diseased or dead vegetation.

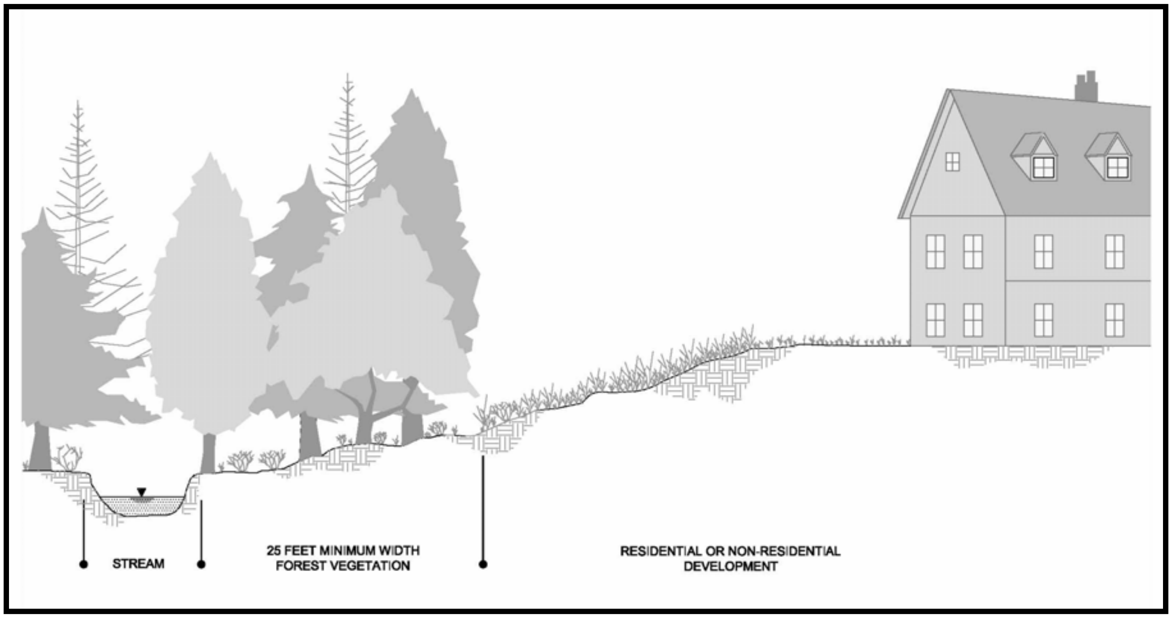
Figure 6-3 presents an example of meeting a vegetative target for a buffer located on a stream.

6.2.4.2 Vegetation Restoration

Vegetative restoration or enhancement of a buffer area that is initiated by the property owner or developer may require prior approval by the local jurisdiction. Alternately, the local jurisdiction may require the property owner to enhance or restore an existing buffer if the buffer area does not meet, or will not meet through natural vegetative succession, the standards necessary for the intended use of the buffer (e.g., provide stream canopy, provide stormwater filtration). All enhancement and restoration efforts shall conform to the following requirements.

1. Restoration activities must be performed in accordance with any and all applicable Federal, State and local permits.

Figure 6-3. Example of a Streamside Vegetated Buffer



2. Newly planted vegetation shall be native, riparian species.
3. All areas of the buffer being restored must be planted with vegetation that is appropriate to achieve the vegetative targets stated in section 6.2.4.1 above.
4. All areas of the buffer being restored must be stabilized against erosion.
5. Areas that will consist largely of grasses after restoration must be seeded at a rate sufficient to provide healthy, dense, permanent vegetative cover for 100% of the area within one growing season. Mulch, pebbles, wood chips and other non-vegetative ground cover is not acceptable for buffer restoration.
6. Where the removal of vegetation would cause a reduction in the amount of stream canopy by 50% or more, revegetation with native plants is required to provide the cover of the previous canopy at a minimum. For areas where such vegetation removal would cause a reduction in the amount of streambank vegetation, revegetation with native plants is required to return the amount of vegetative cover to its previous state, at a minimum. To reduce the potential for streambank erosion, revegetation measures along streambanks must include sufficient erosion control measures, such as turf reinforcement mats, erosion control blankets, straw wattles, to stabilize the area in the short and long term.
7. To increase the chances for the health of the vegetation in the buffer area, the plant species, density, placement, and diversity of the vegetation to be placed in the buffer must be appropriate for stream, wetland, and pond/lake buffers to achieve the vegetative target that is defined for the buffer in section 6.2.4.1 above, either as restored or through natural succession. Planting and long-term maintenance practices must also be appropriate and properly performed.
8. When enhancement or restoration is required by the local jurisdiction, a Buffer Restoration Plan must be prepared and submitted with the Water Quality Management Plan. The Buffer Restoration Plan shall contain the following contents, at a minimum.
    - b) Basic application information, including:
        - i) a description of the need for the buffer restoration;

ii) the dates of the development of the buffer enhancement plan and date of any revisions;
iii) location map showing the property in relation to adjacent properties, streets, and nearby watercourses;
iv) name, address, email address, and phone number of property owner;
v) name, address, email address, and phone number of the applicant, if different from the property owner.

c) If the Buffer Restoration Plan is submitted as a component of a Water Quality Management plan, a the plan should show the location of the buffer(s) in relation to the existing or planned development and to any streams, wetlands, lakes or ponds. The plan should display the area proposed for restoration, showing the limits of disturbance, grubbing, and grading (if permitted).

d) Best management practices for erosion prevention and sediment control during the vegetation restoration or enhancement.

e) Any existing or proposed stream crossings or buffer encroachments. Copies of state and/or federal permits allowing the crossing or encroachment, if applicable.

f) Description and/or drawings indicating the species and density of proposed vegetation, in accordance with the vegetation requirements stated in this chapter. Vegetation mortality must be accounted for all planting densities that are proposed.

g) Descriptions and/or drawings indicating the planting practices that will be employed.

h) Maintenance and monitoring plan for one full growing season, including specification of proposed watering plans and schedule.

i) An implementation schedule for buffer restoration activities. This schedule should be presented in relation to other site grading/construction activities, if such other activities will occur during buffer restoration.

j) One (1) year after completion of the restoration or enhancement activity, the portion of the construction bond that is covered under the Buffer Restoration Plan can be released provided that the enhancement area has been restored or enhanced as required, that soils within the buffer area are stable, and that buffer vegetation is healthy.

6.2.4.3 Vegetation Maintenance and Buffer Disturbances

Maintenance of the vegetation located in a buffer area can be performed without prior approval by the local jurisdiction. Management and maintenance of the vegetated buffer includes specific limitations on the alteration of vegetated conditions. The following vegetation management activities are allowed, <u>provided that soil disturbance is minimized and the intended functions of the vegetated buffer area are preserved</u>:

1. The removal or planting of individual trees or vegetation as needed to maintain the overall health and function of vegetation in the buffer area. The removal of non-native, nuisance vegetation, or the removal of individual trees that are in danger of falling and causing damage to dwellings or other structures, are dead or diseased, or have been heavily damaged by storms. Root wads or stumps should be left in place, where feasible, to maintain soil stability.

2. The limited pruning of trees and woody vegetation provided that the health and function of the vegetated buffer area are not compromised.

3. Minor landscaping to repair erosion, bare spots, or sparsely-vegetated areas.

4. Infrequent ground cover maintenance activities such as weed-eating. Such activities should be minimized and must not result in the removal (either temporary or permanent) of ground cover vegetation.
5. Disturbances necessary for the construction of allowable uses, as defined in section 6.2.5. Approval of a Buffer Restoration Plan by the local jurisdiction is required prior to any construction activity in a vegetated buffer area.
6. Disturbances as required to establish and/or restore buffer areas in accordance with section 6.2.4.2.
7. Grubbing, clearing, bush-hogging, and other mass vegetation removal activities are prohibited without prior approval of a Buffer Restoration Plan. When the removal of vegetation would cause a reduction in the amount of stream canopy by fifty percent (50%) or more, re-vegetation with native plants is required for the entire area where the canopy was removed. For areas where such vegetation removal would cause a reduction in the amount of stream bank vegetation, re-vegetation with native plants is required to meet the previous coverage.
8. The application of herbicides, pesticides, and fertilizers in a buffer area is prohibited.

6.2.4.4 Additional Guidance on Buffer Vegetation and Restoration

More detailed guidance and information on streambank and buffer restoration techniques, plants and planting guidelines and native plant species can be found from the following sources:

- Tennessee Valley Authority's Riparian Restoration webpage, located at www.tva.com/river/landandshore/stabilization/index.htm
- Tennessee Valley Authority's Native Plant Finder webpage, located at www.tva.com/river/landandshore/stabilization/plantsearch.htm;
- Banks and Buffers: A guide to selecting native plants for streambanks and shorelines. Contact information to obtain this publication is provided at www.tva.com/river/landandshore/stabilization/websites.htm;
- Knoxville-Knox County Tree Conservation & Planting Plan, published by MPC and available at www.knoxmpc.org
- the Tennessee Exotic Plant Pest Council website, located at www.tneppc.org; and
- the Natural Resource Conservation Service (NRCS).

The introduction or propagation of plants considered as nuisance, non-native (also termed "exotic") and/or invasive plant species, such as honeysuckle, privet, ivy and kudzu is strongly discouraged near the buffer area. In addition, such plants are prohibited from being planted in a buffer area, as part of restoration or maintenance. Guidance on non-native species in Tennessee can be found at the Tennessee Exotic Plant Pest Council website, located at www.tneppc.org.

6.2.5 Buffer Use Restrictions

6.2.5.1 Prohibited Uses

The following uses or activities are prohibited within vegetated buffers:

1. Spraying, filling, dumping, and animal grazing;
2. Use, storage, or application of pesticides, herbicides, fertilizers, or household or commercially-generated wastes;
3. Concentrated animal lots or kennels;

4. The storage of motorized vehicles, except for temporary parking associated with maintenance of the buffer or allowed use areas, or emergency use;
5. Creation of impervious surfaces, except for those included in approved stream crossings or other approved uses
6. Other uses as deemed by the local jurisdiction to have the potential to generate higher-than-normal pollutant loadings.

6.2.5.2 Allowed Uses

The following structures or uses are allowed in the vegetated buffer area, subject to the prior approval of the local jurisdiction and the specific design or maintenance features listed for each approved use.

1. Stream crossings, water access structures (i.e., docks), and utilities/utility access areas. The following requirements shall apply to such areas:
    a) An analysis must be conducted to show that there is no economically-feasible alternative to the proposed use.
    b) The right-of-way or access area width and length must be the minimum needed to allow maintenance access and installation.
    c) The angle of a buffer crossing shall be within 15 degrees of perpendicular to the stream or buffer in order to minimize clearing requirements. A deviation from perpendicular up to 15 degrees may be allowed through administrative approval from the local jurisdiction if it is determined that there is no other viable alternative.
    d) The number of buffer crossings shall be minimized within each development, and no more than one (1) crossing is allowed for every 1,500 feet linear feet of vegetated buffer. Additional crossings may be approved by the local jurisdiction if justified by traffic, safety, or access issues. Where possible, the design of roadways and lots within a development should be arranged so that all streams are either to the rear or side of individual lots, and never along the front of lots.
2. Trails, greenways or bike paths. The following requirements shall apply to such areas:
    a) Tree canopy must be preserved;
    b) The maximum width of the path must not exceed 10’;
    c) The minimum distance between the top of the streambank and the trail or path is 10’.
3. Stream restoration projects, facilities and activities;
4. Conservation uses, wildlife sanctuaries, nature preserves, forest preserves, fishing areas, and passive use areas such as parks, picnic areas, and yards as long as they do not have impervious surfaces. Passive use areas are defined as private or public use areas that do not require hardened, impervious surfaces to be constructed. Passive recreation areas do not include golf courses, ball fields that require the construction of impervious surfaces or the maintenance of open soil areas (such as baseball infields), picnic shelters or parking. The following requirements shall apply to all conservation and passive use areas:
    a) The removal of trees and woody understory vegetation shall be minimized and shall under no circumstances affect the ability of the buffer to function as intended.
    b) Asphalt, concrete, packed gravel, and other impervious paving surfaces are prohibited. Note, a variance to this requirement may be granted for trails, greenways or bike paths

that are being linked to public use trails, greenways or bike paths or are included as part of redevelopment of previously developed land. Such variance shall be subject to the following requirements:

i. Any impervious surface must be used solely for pedestrian or bicycle access/use, no car traffic is allowed.

ii. There must be no reduction of tree canopy of the buffer area. Trees and vegetation destroyed for purposes of the pathway must be replanted within the buffer area.

iii. The maximum width of the impervious surface shall be 10-feet. The use of gravel, other semi-permeable materials, or pervious pavement for the trail or bike path are encouraged.

iv. The minimum distance of the streamside edge of the pathway to the top of bank or edge of the stream (or other waterbody) is one-half the width of the buffer. For example, for a buffer having a width of 25 feet, the pathway could be located no closer than 12.5 feet from the top bank or edge of the stream.

c) Picnic facilities shall be limited to picnic benches and trash receptacles. Roofed enclosures, paved or landscaped picnic pads, and grills/fire pits are prohibited.

d) Educational signs about the buffer area, vegetation, or function are encouraged in picnic areas and pathways that are placed in vegetated buffers located in common areas or on public lands. The local jurisdiction may assist property owners with such signage (see section 6.2.6.3 for more information).

e) Where traffic safety or access to allowed use areas as defined above would be negatively affected by the presence of trees and wood vegetation required by this chapter, areas immediately-surrounding allowed use areas shall be vegetated with dense, native grasses.

6.2.6 Protection of Vegetated Buffers

Buffers must be protected prior to, during, and perpetually after construction in order to prevent stream bank erosion and protect the stream from thermal impacts. Buffer areas must remain protected from land disturbance, vegetation removal, construction of impervious surfaces, and discharges of sediment and other construction-related wastes during development activities.

6.2.6.1 During Construction

The following requirements shall be applied during clearing, grading and construction of the new development or redevelopment:

1. Unless otherwise provided herein, all areas that are required to be designated as vegetated buffers after construction has been completed shall remain protected from land disturbance, vegetation removal, construction of impervious surfaces, and discharges of sediment and other construction-related wastes during development activities.
2. Vegetated buffers shall be clearly identified on all construction drawings, and marked with the statement “Vegetated Buffer Area. Do not disturb.”
3. During construction vegetated buffers must be cordoned-off with a highly visible barrier, such as orange construction fencing, and cannot be encroached upon or disturbed unless they are being established, restored, or enhanced. Encroachments and disturbances caused by buffer enhancement and restoration efforts shall be minimized to the maximum degree possible.

4. Where the requirements of this chapter and another regulation, such as the State of Tennessee General NPDES Permit for Discharges of Stormwater Associated with Construction Activities, conflict or overlap, the regulation that is more restrictive or imposes higher standards or requirements shall prevail.

6.2.6.2 After Construction

Once construction has ceased on a project, the vegetated buffer must be maintained in accordance with the recorded Covenants for Maintenance of Stormwater Facilities and Best Management Practices. In order to provide for long-term protection and maintenance, it is required that the vegetated buffer be protected in perpetuity by placing the buffer in a permanent water quality or other easement that is recorded with the property's deed. The property owner is responsible for the maintenance and protection of the buffer area.

6.2.6.3 Signage

Permanent boundary marker signs may be required by the local jurisdiction prior to recording the final plat or issuance of a Certificate of Occupancy to ensure that adjacent property owners are aware of the buffer. Further, replacement of such boundary markers that have been removed or destroyed may be required by the local jurisdiction. The following general policies shall apply to buffer boundary markers:

1. Generally, buffer boundary markers must be located on the lot lines at the intersection of the landward edge of the buffer, and at other locations which will approximately delineate the buffer boundary. For single lot site developments, markers, if required, shall be posted every 100 feet along the buffer boundary. For subdivisions where multiple lots are located along the buffer, it is recommended that a buffer boundary marker be located at the intersection of every other lot line with the landward edge of the buffer.
2. Buffer boundary markers shall include the statement "Vegetated Buffer Area. Do not disturb."
3. Where possible, the markers should be mounted on a tree larger than three (3) inches in diameter. Where it is not possible to mount the marker to a tree, a treated wood, metal, or plastic signpost must be used. The post must extend below the ground surface at least twenty-four (24) inches.
4. The boundary markers must be mounted between four (4) and six (6) feet above the ground surface.

6.2.7 Percent TSS Removal

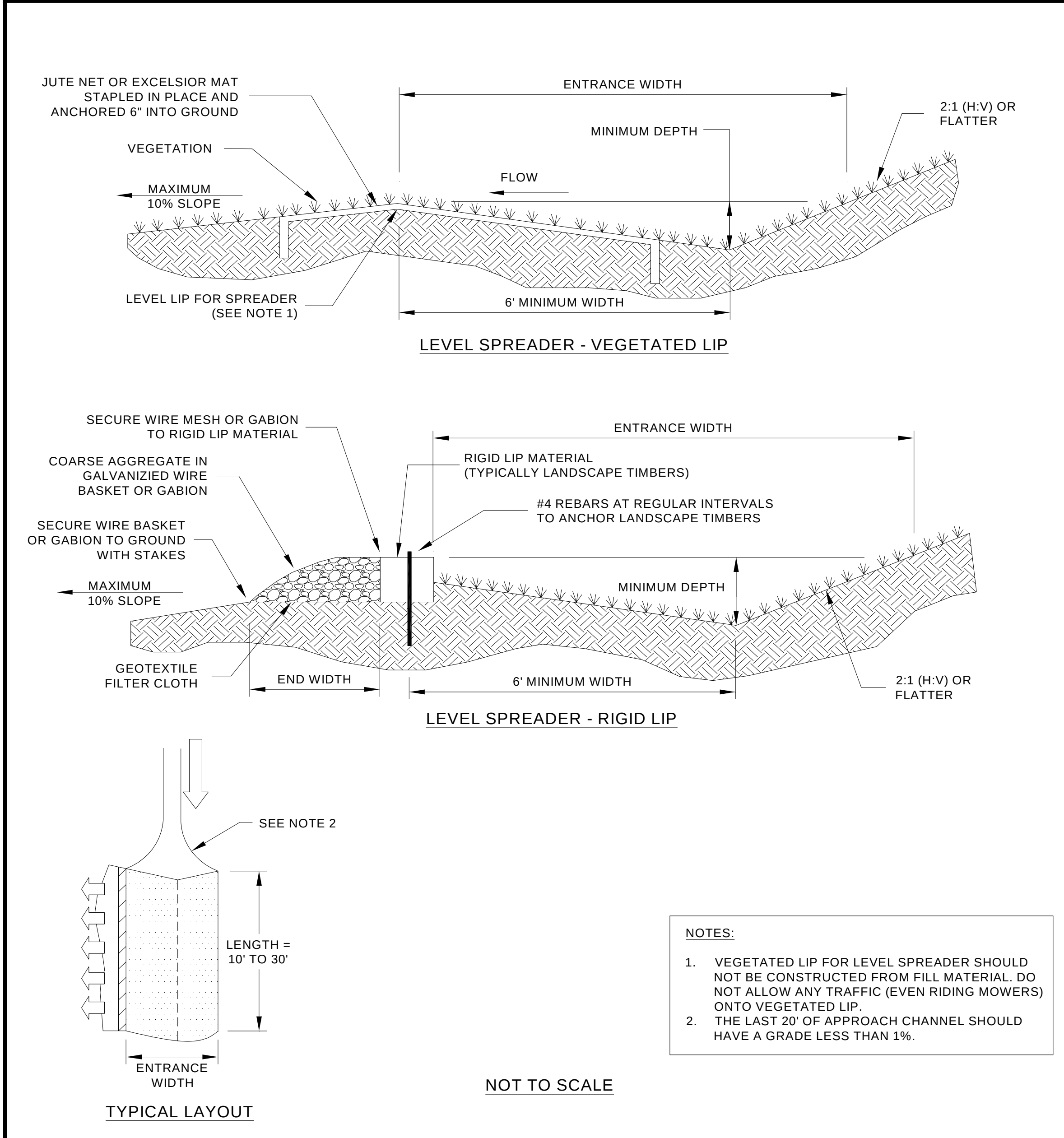
Vegetated buffers that have been established, restored, and/or preserved in accordance with the requirements of this Chapter can be used towards the required, calculated percent TSS removal of stormwater runoff that discharges through the buffer as sheet flow. Policies and guidance associated with the calculation of percent TSS removal are contained in Chapter 3 of this manual. Per Chapter 5, section 5.2.6, of this manual, sheet flow to vegetated buffers that meet the minimum requirements can receive an 80% TSS removal calculated value. Stormwater that has already been treated to the 80% TSS removal standard can bypass the buffer in a pipe or channel. The local jurisdiction will provide guidance on design of outlets that will remain stable and not cause channel erosion.

6.3 Level Spreaders

6.3.1 Description

Level spreaders are structures that are designed to dissipate energy of concentrated, potentially erosive, flow and distribute it as low velocity sheet flow uniformly over a stabilized, typically vegetated, area. The resultant sheet flow has a high surface contact area and therefore enhances infiltration and pollutant filtration and reduces the potential for soil erosion. This process of transitioning concentrated flows of stormwater runoff into sheet flow is essential for maintaining the function and effectiveness of vegetated buffers. Engineering detail of a typical level spreader is shown in Figure 6-4.

Figure 6-4. Level Spreader
(Source: City of Knoxville Land Development Manual, January 2001)



Level spreader primary applications:

- to disperse shallow concentrated or channelized stormwater runoff from impervious areas or upstream stormwater outfalls to a water quality BMP, such as a filter strip, water quality or other buffer, or other vegetated area; or,

- for land draining to vegetated buffers that has more than a three percent (3%) slope: or,
- for outlet diversion (i.e., the release of small volumes of concentrated flow from diversions when conditions are suitable).

Level spreader design elements:

- A pipe, ditch, or swale through which concentrated flow enters the spreader;
- An energy dissipator that slows the water;
- A level lip provided by the construction of a berm, concrete chute, or other permanent material or a shallow linear trench. The purpose of this component is to distribute runoff perpendicularly over the lip or through the trench at the same depth for the entire length of the spreader.

6.3.2 Design Standards

Level spreaders are difficult to construct properly, and therefore a high degree of care must be taken to construct the spreader lip completely level. A spreader lip that slopes to one side or has notches or depressions along its length will result in concentrated flow discharging over the lip, defeating the purpose of the spreader. Improperly designed level spreaders can reduce the effectiveness of filter strips and buffer areas to remove pollutants by filtering of runoff, and can increase the potential for erosion in vegetated areas to which the level spreader discharges.

All level spreaders shall conform to the design standards listed below.

For impervious surface runoff applications:

- The capacity for the level spreader is determined in the design of the structural BMP or vegetated buffer to which it discharges. Design guidance for structural BMPs is presented in Chapter 4.
- The spreader shall run linearly along the entire length of the BMP to which it discharges or along the stream/wetland/pond. In most cases, the spreader will be the same width as the contributing impervious surface. The ends of the spreader shall be tied into higher ground to prevent flow around the spreader.

For all level spreader applications:

- The capacity of the level spreader shall be determined using the peak flow from the 1-year, 24-hour storm. The drainage area shall be restricted so that maximum flows into the spreader will not exceed 30 cfs.
- The minimum depth shall be 6-inches and the minimum width shall be 6 feet for the lower side slope.
- Side slopes shall be 2:1 (horizontal to vertical) or flatter.
- The grade of the spreader shall be 0%.
- The appropriate length, width, and depth of spreader should be selected from Table 6-1.

Table 6-1. Level Flow Spreader Dimensions
(Source: City of Raleigh, 2002)

Design Flow (cfs)	Minimum Entrance Width (ft)	Minimum Depth (ft)	Minimum End Width (ft)	Minimum Length (ft)
0-10	10	0.5	3	10
10-20	16	0.6	3	20
20-30	24	0.7	3	30

- It will be necessary to construct a 20 foot transition section in the diversion channel (formed by the diversion berms) so the width of the channel will smoothly meet the width of the spreader to ensure uniform outflow.
- The last 20 feet of the diversion channel shall provide a smooth transition from the channel grade to the level spreader and where possible, shall be less than or equal to 1%.
- The receiving area below the level spreader shall be protected from harm during construction. Minor disturbed areas shall be stabilized with vegetative measures. A temporary stormwater diversion may be necessary until the vegetation on the level spreader has fully stabilized.
- Level spreaders must blend smoothly into the downstream receiving area without any sharp drops or irregularities, to avoid channelization, turbulence and hydraulic "jumps."
- Level spreaders shall be constructed on undisturbed soil where possible. If fill is used, it shall be constructed of material compacted to 95% of standard proctor test levels for that area not considered the seedbed.
- Immediately after level spreader construction, seed and mulch the entire disturbed area of the spreader.
- The level spreader lip shall be protected with erosion resistant material to prevent erosion and allow vegetation to be established.

6.4 Considerations for Buffer Areas

The minimum requirements for vegetated buffers that are presented in section 6.2 are intended to establish, restore and/or protect buffers for the purposes of streambank stabilization and stream canopy. However, going beyond the minimum requirements should be considered by site developers. Wide, forested buffer areas can provide a multitude of benefits to local stream water quality and are one of a number of best management practices (BMPs) that are available to site developers for incorporation into development plans to meet water quality goals.

PURPOSES OF A STREAM BUFFER:

- Reduce erosion and stabilize stream banks.
- Assist with infiltration of stormwater runoff.
- Control sedimentation.
- Reduce the effects of flood and drought.
- Provide shade to streams.
- Provide and protect habitat for aquatic species and other wildlife.
- Offer scenic value and recreational opportunities.
- Restore and maintain the chemical, physical and biological integrity of water resources.
- Minimize public investment in waterway restoration, stormwater management, and other public water resource endeavors.

Shueler, WPT Summer, 1995
Vegetated Riparian Buffers and Buffer Ordinances, SCDEC

When properly vegetated and preserved, buffers provide a tool for the improvement of stream water quality and habitat. Research has shown that buffers having significant width (e.g., 50 feet and greater) and appropriate dense vegetation (e.g., forest, woody shrubs and dense grasses) will slow and spread-out stormwater runoff from upstream impervious areas, and will filter sediment and the chemicals and pollutants that attach to sediment particles via the trees, shrubs, and grasses that make up the buffer area (Desbonnet et al. 1994). Further, the trees and other vegetation in a buffer provide shade for the stream and buffer area, allowing stormwater runoff that has been heated on roofed and paved areas to cool before reaching the stream and shading the stream to protect it from direct sunlight that heats the stream. The temperature of the stream is important for the protection of the organisms that live in the stream. At higher temperatures, water retains less dissolved oxygen, decreasing the amount available to the aquatic life and resulting in physical stress or death.

Vegetated buffers can also act as a flood and erosion management tool. Buffers slow runoff velocities, increase baseflows, counter channelization of runoff inflows, and reduce inflow volumes through infiltration into the soil and capture in vegetation. These effects can reduce the potential for downstream flooding, and the potential for streambank instability and erosion, both in the buffered area and downstream. Because development in buffered areas is limited, buffers can be helpful for floodplain management, preventing development along the stream edge and, in some cases, the floodplain.

Site developers and design engineers are encouraged to go beyond the minimum requirements stated in this section to protect stream water quality or other environmentally sensitive areas, promote infiltration and filtration of stormwater runoff and provide wildlife habitat. A WQv reduction, called the Vegetated Buffer Reduction, is offered to provide an incentive for wider (50' or greater), more heavily vegetated buffers that can provide additional water quality benefits. The use of this reduction can decrease the WQv that is required for treatment. Chapter 5 of this manual provides more information on the Vegetated Buffer Reduction.

6.5 References

City of Knoxville. *Land Development Manual.* City of Knoxville Engineering Department, Stormwater Division, June 2006.

Desbonnet, et al. 1994. Vegetated Buffers in the Coastal Zone. A Summary Review and Bibliography. Coastal Resources Center, University of Rhode Island.

Knox County, Tennessee. Knox County Stormwater Management Manual Volume 2, Chapter 6 Water Quality Buffers. November 2007.

Shueler, T. *Vegetated Riparian Buffers and Buffer Ordinances.* SCDEC, Summer, 1995.

Table of Contents

CHAPTER 7 — BMP MAINTENANCE AND POLLUTION PREVENTION

This page left intentionally blank

CHAPTER

7

BMP MAINTENANCE AND POLLUTION PREVENTION

7.1 Introduction

The purpose of this Chapter is to provide general information on inspection and maintenance requirements for stormwater quality best management practices (BMPs) and provide general information on pollution prevention on developed properties.

7.2 BMP Inspection and Maintenance

Proper maintenance of stormwater quality BMPs is one of the most important factors in the long-term performance and effectiveness of a Water Quality Management Plan. Property owners or homeowners associations are required to properly maintain BMPs located on private property for the life of the BMP, and therefore must execute protective covenants that include legally-binding inspection and maintenance requirements. The protective covenants are entitled “Covenants for Permanent Maintenance of Stormwater Facilities and Best Management Practices”, and a blank copy is presented in Appendix F of this manual.

Effective, long-term operation and maintenance of BMPs requires a three-phased approach on the parts of the developer, property owner and local jurisdiction. These three phases are as follows.

1) Site Developer: In an effort to reduce maintenance requirements for each development, a developer or site designer should consider the maintenance requirements for each stormwater structural or non-structural BMP when designing a development. To this end, the local jurisdiction strongly encourages site designers to utilize non-structural BMPs and better site design practices to the maximum degree possible, thereby reducing the degree of stormwater maintenance that will be required for the property after construction. Non-structural controls, which are discussed in detail in Chapter 5, generally require very little (and often no) maintenance and can reduce the size of any structural BMPs needed to treat stormwater runoff quality. The developer and site designer should then choose, design and construct structural BMPs that have the lowest relative long-term maintenance requirements based upon the site constraints.

   The developer and site design engineer are required to submit and certify Record Drawings of the new development or redevelopment that show the actual conditions of the developed site, including stormwater quality BMPs, after construction is completed. Along with the property’s plat, these Record Drawings will serve as the basis for locating BMPs, vegetated buffers and WQv credit areas, and provide a baseline understanding of BMP design and construction that will be used for inspections and maintenance in the years to follow.

2) Property Owner: After construction, the property owner is responsible to inspect and maintain the BMPs, vegetated buffers, and WQv credit areas in accordance with the guidance provided in this manual. For more information on BMP inspection content, frequency and documentation, refer to the checklist for each BMP provided in Chapter 4 of this manual. Information on WQv credit areas is provided in Chapter 5, and vegetated buffer information is provided in Chapter 6.

3) Local Jurisdiction: Local stormwater quality management regulations give local jurisdictions the authority to perform periodic inspections of water quality BMPs, vegetated buffers and WQv credit areas in order to determine if these elements are being maintained in accordance with local regulations and policies. Corrective actions can be ordered or performed for elements that are determined to be improperly constructed or not maintained. The reader is referred to the local stormwater quality management regulations for more information on jurisdictional authority and penalties if corrective actions are warranted.

7.3 Pollution Prevention After Construction

As noted in Chapter 1, stormwater pollution, or non-point source pollution, comes from many different sources: active construction sites, agricultural practices, forestry practices, and urbanized areas. Some types of urban land uses contribute higher than normal pollutant loadings. Inherent with these types of land uses are the storage, use and/or production of higher amounts of solvents, oils, lubricants, fertilizers, grease, and/or bacteria. If traditional stormwater quality controls are installed in runoff discharges that carry higher pollutant levels, the controls are quickly overwhelmed and stormwater quality downstream suffers. Therefore, for such discharges, additional measures must be taken to protect local streams, rivers and lakes from these higher pollutant loadings.

Pollution prevention begins during active construction. However, pollution prevention must be practiced throughout the life of the site and is the responsibility of the property owner and business/activity operator. Pollution prevention activities should be tailored to capture typical pollutants from the land use activity occurring on the site. General guidance for land uses that are often identified as having a higher than normal pollutant potential is presented in the following paragraphs.

- **Vehicle maintenance, washing or storage facilities.** Pollution prevention activities for vehicle maintenance, washing, or storage land uses must focus on spill prevention and cleanup, oil and other fluid and material recycling, pre-treatment of wash water or runoff from maintenance areas, staff education on proper pollution prevention techniques, and customer education about the activities that are or are not acceptable on the premises. For businesses where vehicles will be stored, pollution prevention activities must also include routine inspection of the vehicles for leaks or discharges. Drip pans must be used to capture leaks and discharges until the vehicle can be maintained or fluids should be drained completely from vehicles that will remain unused. Discharges of wash water resulting from the hosing or cleaning of vehicles, equipment and/or facilities is considered an illegal non-stormwater discharge. Therefore, wash water must be prevented from entering the stormwater system. These activities could include blocking the stormwater system or diverting the wash water into a pre-treatment measure and then into the sanitary sewer system.
- **Recycling and salvage yard facilities.** Where the land use is a business that recycles or salvages vehicles or other equipment, the pollution prevention practices for that site should address draining the equipment of all fluids before storage. If the storage are is uncovered, pre-treatment controls are required to treat additional pollutants that could result from the storage or deterioration of the equipment or vehicles before the runoff discharges to traditional best management practices (BMPs), such as those discussed in Chapter 4.
- **Restaurants, grocery stores, and other food service facilities.** Grease and organic pollutants are pollutants that are typically encountered around restaurants, grocery stores, and other food service facilities. Pre-treatment to remove such pollutants prior to discharging to traditional BMPs is required, in order to prevent clogging of downstream BMPs and the stormwater system. As well, wash water from equipment and/or facility cleaning activities must either be discharged to the sanitary sewer or be pre-treated prior to discharging to a stormwater quality BMP.
- **Facilities that temporarily or permanently house animals outside.** Animal housing

facilities, such as veterinary clinics, boarding facilities, livestock stables, hatcheries and animal shelters, have the potential to deliver higher than normal bacterial loadings to the stormwater system. High counts of bacteria in streams and rivers can cause water quality impairments, but can also cause illnesses in people. Pollution prevention practices for these types of facilities must include pet waste management practices, such as collecting and properly disposing of pet waste at landfills or wastewater treatment facilities. Animal bedding should be removed when soiled and properly disposed. Wood shavings or chips must not be allowed to migrate into the stormwater system.

7.4 Sediment Disposal for Structural BMP Maintenance

Many of the structural BMPs (presented in detail in Chapter 4 of this manual) that are utilized to prevent stormwater pollutants from entering the waters of the state will accumulate sediment deposits over time and will require maintenance and cleaning to ensure that they continue to work at optimum efficiency. Depending on the characteristics of the drainage area to each structural BMP, there could be a wide nature of substances contained within the sediments. The appropriate sediment disposal method will depend on the type of contamination, if any, in the soil. Proper assessment and disposal of accumulated sediment is necessary to ensure that the sediment removed from structural BMPs does not cause discharge of pollutants to the environment. The text in this section shall be regarded as local jurisdictional policy for proper assessment and disposal of accumulated sediments that are removed from structural BMPs. (Note: the text below was adapted from the City of Knoxville Land Development Manual – Policy 11, June 2003.)

When properly designed, structural BMPs will accumulate significant quantities of sediment over time. Sediment gradually reduces the available stormwater storage capacity. A rule of thumb for BMPs such as detention ponds, extended detention ponds and stormwater ponds is that approximately 1% of the storage volume capacity associated with the 2-year design storm can be lost annually due to accumulated sediment. Therefore, approximately 20% of a pond's total storage capacity can be lost within 20 years.

The actual sediment accumulation rate is dependent upon a number of factors including watershed size, facility sizing, upstream construction, nearby industrial activities and land uses, numbers of leaking vehicles, use of sand and salt during winter, etc. Thick grass and vegetation will retain sediment and silt at a faster rate.

In addition to long-term maintenance, sediment disposal is usually necessary during the construction process. Erosion prevention and sediment control practices and devices are not 100% effective at reducing and eliminating all sediment. Therefore, the developer must ensure that the designed detention volume has been restored and that all graded surfaces have been completely stabilized at the end of construction.

Structural BMPs shall be inspected on a regular basis to determine the impact of existing sedimentation on the capacity. The frequency of inspection is dependant upon the upstream land use(s), type of BMP, and other factors. Inspections should occur during dry weather and wet weather conditions. In general, remove sediment prior to significant accumulations using a combination of equipment methods and hand shoveling. Typical intervals for sediment removal will be every 5 to 7 years for some BMP types, 10 to 20 years for others. Typical intervals for sediment removal for sediment forebay or other pretreatment settling basin will be once a year. Detailed guidance on the frequency of inspection and maintenance activities relating to sediment accumulation specific to each structural BMP that is presented in this manual is provided in Chapter 4.

Guidance for Assessment and Disposal:

1. If the structural BMP meets any of the following criteria, then the structural BMP owner must contact the Tennessee Department of Environment and Conservation (TDEC) for further regulations and recommended disposal guidelines.

    a. known contaminants are contained in the stormwater runoff that discharges to the structural BMP or in the sediment that has accumulated in the structural BMP.

    b. the structural BMP receives stormwater runoff from an industrial site.

    c. the structural BMP receives stormwater runoff from a fueling center.

    d. The structural BMP receives stormwater runoff from one or more commercial businesses with a total parking area of at least 120,000 square feet or 400 parking spaces.

    e. the local jurisdiction has reason to believe that contaminants are present based upon scientific or engineering information.

    In all cases, treat sediment from structural BMPs as potentially hazardous soil until proven otherwise. Sediments should be sampled and identified before removal and disposal operations proceed. Contact the local office of TDEC – Division of Water Pollution Control to discuss special disposal procedures.

2. If the structural BMP does not meet any of the above criteria, or if the sediment has been tested and is determined to be free of contamination, then the following disposal practices are allowed:

    a. disposal at a Class III or Class IV landfill.

    b. use for fill material, cover material or land spreading on the project site.

    c. other disposal options as approved by the local jurisdiction.

All sediment which is disposed onsite must be prevented from re-entering the structural BMP, or entering any other BMP, drainage channel or culvert, natural creeks or streams, or any other component of the stormwater drainage system.

APPENDIX A – Definitions

Note: see any applicable ordinances for additional definitions

The definitions provided in this appendix shall apply to the requirements contained in this manual. These definitions pertain to stormwater quality management only. The reader is referred to the local municipal ordinances and regulations for definitions that are not included in this section.

Active channel. The area of the stream that is most subject to water flow and that includes the portion of the channel below the top-of-bank.

As-Constructed Certification. As-constructed, field-verified plans signed and sealed by a registered professional engineer and/or a registered land surveyor, both licensed to practice in the State of Tennessee, showing contours, elevations, grades, locations, drainage and hydraulic structures, and detention basin volumes.

Building. Any enclosed structure intended for shelter, housing, or enclosure of persons, animals, or chattel.

BMP Operations and Maintenance Agreement. A legal document executed by the property owner, or a homeowners' association as owner of record, and recorded with the Register of Deeds which guarantees perpetual and proper maintenance of stormwater facilities and best management practices.

Design Plan. The review of a developments design plan by the local engineering and/or planning department or agency, and/or other administrative agencies or utilities for conformance to applicable development regulations and standards.

Design Plan Review. The review of a development's design plan by the local engineering and/or planning department or agency, and/or other administrative agencies or utilities for conformance to applicable development regulations and standards.

Developer. An individual, partnership corporation, or other legal entity or agent thereof which undertakes the activities covered by the local municipality's zoning, subdivision, floodplain, and Stormwater Management Ordinances.

Easement. The right to use another person's property, but only for a limited specifically named purpose; the property owner generally continues to make use of such land since he has given up only certain, and not all, ownership rights.

Easement Area. A strip of land over, under, or through which an easement has been granted.

Engineer. A qualified civil engineer registered and currently licensed to practice engineering in the State of Tennessee.

Engineering. The preparation of plans, specifications, and estimates for, and the contract administration of the construction of streets, drainage facilities, utilities and other similar public works installed within a subdivision or site development for public or private use.

Erosion Prevention and Sediment Control Plan. A written plan (including drawings or other graphic representations) that is designed to eliminate and/or reduce erosion and off-site sedimentation from a site during the active construction phase of development.

Karst. A type of topography that is formed over limestone, dolomite, or gypsum by dissolving or solution, and that is characterized by closed depressions or sinkholes, caves, and underground drainage.

Lot. A parcel of land which is or may be occupied by a building and its accessory building or uses customarily incidental thereto, together with such yards or open spaces within the lot lines as may be required by the minimum subdivision regulations or the zoning ordinance of the municipality within which the lot is located.

Pond. An inland body of standing water that is usually smaller than a lake.

Priority Sites. Developments that discharge directly into, or immediately upstream from, waters the State recognizes as impaired for siltation or those waters designated as high quality waters. A property is considered to have a direct discharge if the stormwater runoff from the property does not cross any other property before entering waters of the State.

Review. The study of a design plan, stormwater management plan or other engineering documents by the local municipal engineering department and/or planning agency, and other administrative agencies for conformance to applicable development regulations and standards or previously submitted and approved plans.

Reviewing Agency. An agency which has responsibility for evaluation and verification of concept plans, design ponds, final plats, or other engineering documents.

Sinkhole. A depression characterized by closed contours on a topographic map. A sinkhole throat, or opening to the subsurface, may or may not be visible. Field verification may be required in areas where the depth of the depression is below the tolerance of currently available topographic mapping.

Top of Bank. The uppermost limit of the active channel of a stream containing normal flows, usually marked by a break in slope.

Utility, public or private. Any agency which under public franchise or ownership, or under certification of convenience and necessity provides the public with electricity, natural gas, steam, communication, rail transportation, water, sewage collection, or other similar service.

Vegetation. Collection of plant life, including trees, shrubs, bushes, and grasses.

Zoning Ordinance. The duly adopted Zoning Ordinance of the local municipality where the proposed development will occur.

This page intentionally left blank

APPENDIX B – Relevant Contacts

Table B-1. Contact Information for Relevant Government Agencies

FEDERAL	*STATE*	*LOCAL*
Department of Agriculture **Natural Resources Conservation Services (NRCS)** 675 U.S. Courthouse 801 Broadway Nashville, Tennessee 37203 **(615) 736-5477**	**TDEC – Environmental Field Office** **Johnson City Field Office** 2305 Silverdale Road Johnson City, Tennessee 37601 **(423) 854-5400**	**City of Bristol, TN** Public Works & Engineering 212 Blackley Road Bristol, Tennessee 37620 **(423) 989-5566**
Department of Army **U.S. Army Corps of Engineers** **Nashville District** P.O. Box 1070 Nashville, TN 37202-1070 **(615) 736-5181**	**TDEC - Department of Water Pollution Control** L&C Annex, 6th Floor 401 Church Street Nashville, Tennessee 37243-1524 **(615) 532-0625**	**City of Elizabethton** Public Works 136 South Sycamore Street Elizabethton, Tennessee 37643 **(423) 547-6341**
Department of the Interior **U.S. Geological Survey (USGS)** 640 Grassmere Park, Suite 100 Nashville, TN 37211 **(615) 837-4700**	**TDEC- Division of Water Supply** L&C Tower, 6th Floor 401 Church Street Nashville, Tennessee 37243-1549 **(615) 532-0191**	**City of Johnson City** Public Works 209 Water Street Johnson City, Tennessee 37601 **(423) 434-6080**
Federal Emergency Management Agency **(FEMA) Region IV** **Mitigation Division** Koger Center-Rutgers Building Atlanta, Georgia 30341 Maps: Toll free 1-877-fema-map **General: 1-770-220-5200**	**Tennessee Wildlife Resources Agency (TWRA)** **Ellington Agricultural Center** P.O. Box 40747 Nashville, Tennessee 37204 **(615) 781-6643**	**City of Kingsport** Public Works Suite 225 City/County Building 400 Main Street Kingsport, Tennessee 37660 **(423) 224-2727**
U.S. Fish & Wildlife Service (USFWS) 446 Neal Street Cookeville, TN 38501 **(931) 528-6481**		

This page left intentionally blank

APPENDIX C

Plan Submittal Checklists

This Appendix contains the following plans submittal checklists:

Appendix C1 - Water Quality Management Plan Checklist
Appendix C2 – Special Pollution Abatement Plan Checklist

This page left intentionally blank

WATER QUALITY MANAGEMENT PLAN CHECKLIST

Date:_______________________________ Number of times reviewed (including this one):_____________________

Project Name:____ Type of review requested:__________________

Address:____

Zoning Classifications:__________________________ Variances? __________________________ ☐ Yes ☐ No

Nature of Variances:____

This checklist presents the required elements of a water quality management plan. This checklist must be submitted to the local jurisdiction along with the water quality management plan. Each element presented in this list must be checked "Yes", as applicable to the site. Checks placed under the "No" column must be justified in a written statement attached to this checklist. Elements of the water quality management plan that are not applicable for the site must be marked as "N/A".

GENERAL INFORMATION

☐ Yes ☐ No ☐ N/A **1. Date(s) of preparation and any revision(s).**

☐ Yes ☐ No ☐ N/A **2. Seal/signature of responsible engineer.**

3. Vicinity map including:

☐ Yes ☐ No ☐ N/A a. North arrow

☐ Yes ☐ No ☐ N/A b. Scale

☐ Yes ☐ No ☐ N/A c. Adjacent roadways

☐ Yes ☐ No ☐ N/A d. Boundary lines of site

☐ Yes ☐ No ☐ N/A e. Onsite and nearby watercourses

☐ Yes ☐ No ☐ N/A f. Other necessary information to locate the development site

4. Maps (to scale) which clearly show:

a. The following lines with accurate bearings and distances:

☐ Yes ☐ No ☐ N/A - Property boundaries

☐ Yes ☐ No ☐ N/A - Lot lines

☐ Yes ☐ No ☐ N/A - Right-of-way lines of streets and/or Joint Public Easements

☐ Yes ☐ No ☐ N/A - Utility access or other easements

b. The location of the

☐ Yes ☐ No ☐ N/A - 100-year floodplain

☐ Yes ☐ No ☐ N/A - 100-year regulatory floodway

☐ Yes ☐ No ☐ N/A - Required minimum floor elevations (MFEs)

☐ Yes ☐ No ☐ N/A c. An Environmental Features Inventory; which shows the boundaries of streams (stream names must be shown if known), wetlands, sinkholes, springs, steep slopes (≥15%), forested areas and grassed areas.

d. Vegetated Buffers

☐ Yes ☐ No ☐ N/A - Location, width, outer boundary, and zone boundaries (on streams)

☐ Yes ☐ No ☐ N/A - The statement "Vegetated Buffer Area. Do Not Disturb" clearly shown.

☐ Yes ☐ No ☐ N/A - A description of the existng and proposed (if different from existing) vegetation in the vegetated buffer areas must be included on the site plan, or as a separate description. For example, a statement on the site plan such as “undisturbed forest vegetation”, or “early successional forest” is sufficient for a stream buffer provided that the existing vegetation, in fact, meets one of these descriptions.

☐ Yes ☐ No ☐ N/A e. Dimensioned existing and proposed structures on and within 15 feet of the property boundaries

☐ Yes ☐ No ☐ N/A f. Roof drainage directions

☐ Yes ☐ No ☐ N/A g. Finished floor and grade at foundation elevations of all existing structures

☐ Yes ☐ No ☐ N/A h. Cut and fill quantities for site work

i. Impervious area information for the site

☐ Yes ☐ No ☐ N/A - For non-residential sites, and for residential subdivisions or lots where the location and footprint of impervious surfaces are known, provide location and footprint area for all impervious surfaces, including buildings, roadways, driveways, sidewalks, parking lots, and out-buildings.

GENERAL INFORMATION (CONTINUED)

i. Impervious area information for the site (continued)

☐ Yes ☐ No ☐ N/A - For residential subdivisions where the location(s) and footprint(s) for buildings are unknown, provide the impervious footprint for roadways, and the assigned % impervious value(s) for the site, or different areas of the site, as appropriate for the lot-layout. Percent impervious values are found in Chapter 3 of this manual. This option can only be utilized for residential sites.

☐ Yes ☐ No ☐ N/A **5. Detailed calculations for all site water quality treatment components. Calculations shall include WQv, CPv, %TSS removal, WQv reduction calculations, and design calculations necessary for all BMPs used in the design**

☐ Yes ☐ No ☐ N/A **6. Construction notes, specifications, and design details for any existing stormwater system components**

☐ Yes ☐ No ☐ N/A **7. Recommendations included in the soils engineering or engineering geology report incorporated in the plans and/or specifications**

☐ Yes ☐ No ☐ N/A **8. Dates and reference number of the soils report(s) together with the names, addresses and phone numbers of the firm(s) or individual(s) who prepared the report(s)**

☐ Yes ☐ No ☐ N/A **9. Established benchmark of known elevation to which every other elevation is referenced**

☐ Yes ☐ No ☐ N/A **10. Horizontal control**

☐ Yes ☐ No ☐ N/A **11. The following statement is required on all water quality management plans:**

"Adequate drainage, erosion and sediment control measures, best management practices, and/or other water quality management facilities shall be provided and maintained at all times during construction. Damages to adjacent property and/or the construction site caused by the contractor's or property owner's failure to provide and maintain adequate drainage and erosion/sediment control for the construction area shall be the responsibility of the property owner and/or contractor."

MAINTENANCE INFORMATION

☐ Yes ☐ No ☐ N/A **1.** A map that accurately identifies the water quality BMPs location and components (e.g., water quality basin, micropool extended detention basin, channels, swales, vegetated buffers, etc.) that are located on the property. This map also must show the locations of drainage and access easements. The language used to identify each BMP in the map must be consistent with the BMP names used in this Manual.

☐ Yes ☐ No ☐ N/A **2.** "Inspection Checklist and Maintenance Guidance" sheet(s) for each type of BMP that is located on the property. At a minimum, the appropriate template checklist(s) provided in Chapter 4 of this Manual must be utilized. However, site designers may modify the templates to include inspections and maintenance elements as needed and appropriate for the BMPs.

☐ Yes ☐ No ☐ N/A **3.** An executed copy of the Maintenance Covenants document

OTHER INFORMATION (IF APPLICABLE)

☐ Yes ☐ No ☐ N/A **1.** A copy of correspondence with the US Fish and Wildlfe office concerning any identified Endangered Species on the property.

☐ Yes ☐ No ☐ N/A **2.** A copy of the Special Pollution Abatement Plan.

APPENDIX C2 – Special Pollution Abatement Plan

Please submit Check with Special Pollution Abatement Plan if required by jurisdiction.
Date:

For sections 1-10, include the supporting information in the box provided or attach an exhibit labeling which section it is in reference to. Provide complete data in a legible and clearly organized format.

A) Legal Name of Facility:
B) Mailing Address:
Physical Location:
Watershed Name:
Parcel Number:

C) Supporting Information:

1. Name of contact person for plan compliance, including job title, address, and phone numbers. The contact person shall be responsible for keeping records of incidents such as significant spills of toxic pollutants or other discharges which may affect stormwater runoff quality. The contact person shall document and record all inspections and maintenance activities.

2. Description of the facility, nature of work performed, and type of facility.

3. Attach a site map of the facility with buildings, parking, drives, materials loading and access areas, dumpsters, type of each impervious surface, ditches, pipes, catch basins, drainage basin limits, area of facility, acreage of offsite water drainage onto facility, discharge points to “Water of the State” or “Community Waters” with name of the water or channel. This map will be a minimum scale of 1”=50’.

STAFF USE ONLY

Date Received:	**Reviewer:**	
Plan Number:		

4. Submit an instruction plan to provide employees at all levels within the company a knowledge of methods to prevent stormwater runoff pollution. The plan shall identify periodic dates for such training and methods used. Submit a site-specific spill protection plan that deals with actual hazardous materials and emergency response equipment at the site.

5. A narrative description of significant materials (as defined by 40 CFR 122.26) that are currently or in the past have been treated, stored or disposed outside; method of onsite storage or disposal; materials management practices used to minimize contact of these materials with stormwater runoff for the past three years; materials loading and access area; material disposal area, location and description of existing structural and non-structural control measures to reduce pollutants in stormwater runoff; and a description of any treatment the stormwater receives.

6. Include a record of available sampling data describing pollutants in stormwater discharges, if available. Carefully research using historical data from previous owner/operator, government records, and investigation reports.

7. Include a preventive maintenance program that includes regular inspection and maintenance of all stormwater management devices (such as cleaning grit chambers and catch basins). Maintenance program shall also include inspecting and testing plant equipment and systems to uncover conditions that could potentially cause breakdowns or failures resulting in discharges of pollutants to surface waters or to groundwater.

8. Submit a maintenance schedule for sweeping or vacuuming the facility parking areas to prevent washout from deposited emissions laden with hydrocarbons, oxides, salts, metals, worn pavement particulates, hydrocarbons, trash, debris, garbage, metal, tire particles, brake lining particles and various chemicals from the wear and deterioration of vehicles. In the event of remedial work or action, submit a cleanup schedule for debris or material storage areas.

9. Description of other ways the facility plans to implement programs to reduce the discharge of pollutants to stormwater runoff. Provide estimated quantity of stormwater flow, direction of flow, and an estimate of the types of pollutants which are likely to be present in stormwater discharges associated with industrial activity for each area of the facility. Designate each area of the facility as having high, medium or low potential for stormwater pollution and explain rationale.

10. Include plans, details and specifications that show construction of new structures to protect discharges into “Waters of the State”. Common examples include an appropriately-sized grit chamber, oil skimmer, oil/water separator, media filtration inserts, etc. Vegetative measures such as grassed swales, constructed wetlands, existing woods or a detention basin are commonly used to supplement structural measures.

D) Certification and signatures: Verify that the certification on this plan is read, thoroughly understood, and signed by the appropriate persons.

CERTIFICATION AND SIGNATURE (MUST BE SIGNED BY PRESIDENT, OWNER, OR RANKING OFFICIAL)

"I certify under penalty of law that I have personally examined and am familiar with the information submitted in this document and attached exhibits. Based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of a fine or imprisonment."

Printed Name: ________________________________ Title: ____________________

Signature: ___________________________________ Date: ____________________

ACCEPTANCE OF RESPONSIBILITY FOR PLAN COMPLIANCE (MUST BE SIGNED BY CONTACT PERSON)

"I also certify under penalty of law that I have personally examined and am familiar with the information submitted in this document and attached exhibits. Based on my investigations, I believe that the submitted information is true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of a fine or imprisonment."

Printed Name: ________________________________ Title: ____________________

Signature: ___________________________________ Date: ____________________

(a) Some facilities which are not yet constructed may not have selected a permanent contact person who will ultimately be responsible for plan compliance. In these instances, the contact person may be a technical person within the company who is generally responsible for environmental compliance issues.

(b) The president, owner, or other ranking official who certifies this document is responsible for keeping local government up-to-date concerning the name of the contact person. The president, owner, or other ranking official who certifies this document is also responsible for notifying the local government if he is no longer an official with the company.

If any information changes or is subsequently found to be in error, please resubmit necessary pages of the Special Pollution Abatement Plan along with new signatures and dates.

Submit this plan with the Water Quality Management Plan for the proposed development or redevelopment.

This page left intentionally blank

APPENDIX D

Record Drawing Checklist

This page left intentionally blank

RECORD DRAWING CHECKLIST

Date:________________________________ Property owner:____

Certifying engineer:_____________________________ Certifying surveyor (as-constructed):_______________________________

Project Name:____

Address:____

Proposed use of this property:____

The Record Drawing submittal process is necessary in order for a construction bond or performance bond to be released, as described in the Northeast Tennessee Water Quality BMP Manual.

GENERAL INFORMATION:

☐ Yes ☐ No ☐ N/A **1. Does the title block have same project name, address, and contact persons as original plans?**

☐ Yes ☐ No ☐ N/A **2. Are seal and signature for the certifying Engineer & Surveyor shown on the record drawings?**

☐ Yes ☐ No ☐ N/A **3. Does each record drawing contain survey benchmarks or other reference points?**

☐ Yes ☐ No ☐ N/A **4. Does each record drawing contain a north arrow, bar scale, and coordinates?**

☐ Yes ☐ No ☐ N/A **5. Is construction complete and have disturbed areas been adequately stabilized to prevent soil erosion?**

☐ Yes ☐ No ☐ N/A **6. Are the footprints for all impervious surfaces constructed as part of the approved Water Quality Management Plan?**

☐ Yes ☐ No ☐ N/A **7. Does each record drawing contain the following statement along with the Registered Land Surveyors' stamp, signature, and license number:**
I hereby certify that I have surveyed the land boundaries and easements shown hereon in accordance with accuracy requirements for a Category I survey and that the ratio for precision of the unadjusted survey is not less than 1:10,000. I further certify that I have located all natural and manmade features shown hereon in accordance with the current Standards of Practice as adopted by the Tennessee State Board of Examiners for Land Surveyors. I certify the location, elevation and description of these features.

☐ Yes ☐ No ☐ N/A **8. Does each record drawing contain the following statement along with the registered Engineer's stamp, signature, and license number:**
Based on site observations and/or information provided by a registered Land Surveyor, I hereby certify that all grading, drainage, structures, and/or systems, erosion and sediment control practices including facilities, and vegetative measures have been completed in substantial conformance with the approved plans and specifications.

WATER QUALITY BMPs

☐ Yes ☐ No ☐ N/A **1. Do all plan views correctly show water quality BMPs at a readable scale, with 1-foot contours where 2-foot contours do not show sufficient detail?**

☐ Yes ☐ No ☐ N/A **2. Are locations and invert elevations for all pipe/ditch outfalls into water quality BMPs shown?**

☐ Yes ☐ No ☐ N/A **3. Are BMP and access easements shown and labeled? Are all conflicts avoided?**

☐ Yes ☐ No ☐ N/A **4. Does the plan include accurate details of outlet structures, including all orifices and weirs, such as size, diameter, invert elevation, means of anchoring, underdrain systems, etc?**

☐ Yes ☐ No ☐ N/A **5. Do water quality BMPs provide for the treatment of the water quality volume to a minimum standard of 80% TSS removal, in accordance with the Northeast Tennessee Water Quality BMP Manual? Are computations provided that are adequate to support 80% TSS removal?**

☐ Yes ☐ No ☐ N/A **6. Do water quality BMPs provide for the capture and discharge of the channel protection volume over no less than a 24-hour period? Are computations provided that are adequate to support the channel protection standard?**

☐ Yes ☐ No ☐ N/A **7. Do water quality BMPs provide for the attenuation of the local jurisdiction peak discharge storm events in accordance with the prevailing water quality regulations? Are computations provided adequate to prove attenuation?**

☐ Yes ☐ No ☐ N/A **8. Has minimum freeboard of 1 foot been provided between 100-year storm and top of berm?**

☐ Yes ☐ No ☐ N/A **9. Are manufacturer's identification number, model, and size for all proprietory BMPs shown on the plans?**

☐ Yes ☐ No ☐ N/A **10. Does the property's Operation and Maintenance Manual include and address each type of water quality BMP?**

RECORD DRAWING CHECKLIST (cont'd)

WATER QUALITY BMP INSPECTION and MAINTENANCE:

☐ Yes ☐ No ☐ N/A **1.** A map that accurately identifies the water quality BMPs location and components (e.g., water quality basin, micropool extended detention basin, channels, swales, vegetated buffers, etc.) that are located on the property. This map also must show the locations of drainage and access easements. The language used to identify each BMP in the map must be consistent with the BMP names used in this Manual.

☐ Yes ☐ No ☐ N/A **2.** "Inspection Checklist and Maintenance Guidance" sheet(s) for each type of BMP that is located on the property. At a minimum, the appropriate template checklist(s) provided in Chapter 4 of this Manual must be utilized. However, site designers may modify the templates to include inspections and maintenance elements as needed and appropriate for the BMPs.

☐ Yes ☐ No ☐ N/A **3.** An executed copy of the Maintenance Covenants document

VEGETATED BUFFERS

☐ Yes ☐ No ☐ N/A **1. Are vegetated buffers shown and labeled correctly on drawings (outer boundaries and zone boundaries, if applicable, should be shown)?**

☐ Yes ☐ No ☐ N/A **2. Are vegetated buffer areas clearly marked on the plan with the statement** *"Vegetated Buffer. Do Not Disturb."* **?**

☐ Yes ☐ No ☐ N/A **3. Have permanent markers been installed correctly on the site?**

☐ Yes ☐ No ☐ N/A **4. Is the type of legal instrument (convenants, deed restriction, etc.) that will be used to serve and maintain the buffer stated on the drawing?**

WATER QUALITY REDUCTION AREAS

The following questions pertain to water quality reductions areas only.

1. Which WQv reductions were received in the development of this site (check all that apply):

- ☐ 1. Natural area preservation credit
- ☐ 2. Managed area preservation credit
- ☐ 3. Stream and vegetated buffers credit
- ☐ 4. Vegetated channels credit
- ☐ 5. Impervious area disconnection credit
- ☐ 6. Environmentally sensitive large-lot neighborhood credit

☐ Yes ☐ No ☐ N/A **2. For reductions 1, 2, 3, and 6: Does the plan clearly show the outer boundaries of all open spaces, and indicate the intended vegetation and use of space?**

☐ Yes ☐ No ☐ N/A **3. For reductions 2: Does the plan include a Vegetative Management Plan that indicates how the vegetation in the Managed Area will be managed in a stormwater-friendly manner?**

☐ Yes ☐ No ☐ N/A **4. For reductions 4 and 6: Are the location of the vegetated channels clearly indicated on the drawing and constructed in conformance with design requirements stated in the Northeast Tennessee Water Quality BMP Manual? Provide slope, length, size, and vegetation type (e.g., fescue grass, Bermuda grass, etc.).**

☐ Yes ☐ No ☐ N/A **5. For reductions 5 and 6: Are locations of disconnected downspouts clearly indicated on the drawings and labeled with the statement** *"This downspout shall remain disconnected from the impervious surfaces and shall forever be discharged onto pervious surfaces"* **.**

☐ Yes ☐ No ☐ N/A **6. For reductions 5 and 6: Do impervious area disconnections conform to the design requirements stated in the Northeast Tennessee Water Quality BMP Manual?**

☐ Yes ☐ No ☐ N/A **7. For reductions 6, are the maximum lot density, the total impervious cover percentage, and open spaces shown and correctly labeled on the drawings?**

☐ Yes ☐ No ☐ N/A **8. For reductions 6, is the type of legal instrument (convenants, deed restrictions, etc.) that will be used to limit imperviousness and open space development in the neighborhood indicated on the drawing?**

APPENDIX E

Maintenance Covenants

This Appendix contains a blank copy of the "Covenants for Permanent Maintenance of Water Quality Facilities and Best Management Practices".

This page left intentionally blank

COVENANTS FOR PERMANENT MAINTENANCE OF WATER QUALTIY FACILITIES AND BEST MANAGEMENT PRACTICES

THE TERMS WATER QUALITY MANGAGEMENT FACILITIES AND BEST MANAGEMENT PRACTICES MAY REFER TO: detention basins, retention basins, water quality basins, water quality wetlands, vegetated buffers, swales, pipes, oil/water separators, sand filtering devices, water quality credit areas, etc.

__________________, (an individual/ a Tennessee or other state corporation/ partnership) with its (office/ residence) located at _________________________, (hereinafter "Property Owner") grants these Covenants for Maintenance of Water Quality Facilities and Best Management Practices (hereinafter "Covenants") on this the ______ day of__________.

WITNESSETH:

WHEREAS, The City of ____________ Water Quality Management Ordinance requires property owners to enter into permanent maintenance agreements for water quality and best management practices before the property is developed.

NOW THEREFORE, as a condition of the approval of a Water Quality Management Plan by the City of ________, the property owner warrants, covenants, and grants as follows:

1. The Property Owner warrants that it is the owner of property located in the City of ___________ at _____________(address); **CLT Number:** Map __ Insert _____ _________ Group ______ Parcel __________; and more specifically of record by deed dated ____ in **(Warranty Book ________ Page _____ or as Instrument Number ___)** with the City of _________ Register of Deeds (hereinafter- referred to as the "Property") and that it has the right to grant said Covenants.

2. The Property Owner desires to develop all or a portion of the above described property in accordance with the approved As-Built Certification for the property entitled ______________, dated _______________and prepared by ________ _________ (hereinafter "Plan").

3. The Property Owner will construct and maintain the water quality facilities and best management practices in strict accord with the Plan, specifications, calculations, and conditions required by the City of ________ .

4. The Property Owner will provide a surety bond, letter of credit, or cash bond acceptable to the City of __________ and in an amount to be determined by the City of to guarantee that the water quality facilities and best management practices are constructed in accordance with the plan.

5. To ensure that subsequent property owners have notice of these Covenants

and the obligations therein, the Property Owner will include in all instruments conveying any or all of the above described property on which the water quality facilities and best management practices are located, the specific instrument numbers referencing these Covenants and the recorded subdivision plat indicated in paragraph 12 herein.

6. The Property Owner will provide for adequate long term operation and maintenance of the approved water quality facilities and best management practices described in the Plan to ensure that the facilities and practices remain in proper working condition in accordance with approved design standards and all applicable rules and regulations. The Property Owner shall perform such maintenance activities as described in the attached “Maintenance Guidance and Checklist”, along with necessary landscaping (e.g., vegetation planting or removal, etc.) and trash removal as part of regular maintenance.

7. In order to provide access to water quality facilities and best management practices by personnel, vehicles and equipment, the Property Owner will provide an access easement from a public street in strict accord with the Plan and any conditions required by the Engineering Department. The access easement is twenty (20) feet in width, and has an internal unobstructed, traversable access width located within and along the entire length of the easement. The Property Owner further covenants that no structure or building will be erected on the access easement; that no woody vegetation will be allowed to grow on the access easement; and that no use will be made which will interfere with the use of said easement for access to the facilities. If access to the facilities is obstructed and the City is required to remove the obstruction, the City will follow the notice procedure, double lien, and collection process as set forth in paragraph 9 herein.

8. Property Owner grants permission to the City, its agents and employees, to enter upon the property to inspect and monitor said facilities whenever the City deems necessary and further for the City or its agents to repair, replace, maintain, and reconstruct said facilities as permitted herein.

9. If the City determines that the water quality facilities and/or best management practices are not being maintained in good working order, the City will provide written notice to the current Property Owner to repair, replace, reconstruct, or maintain said facilities within a reasonable time frame. Said written notice must include identification of the property, the water quality facility(ies) or best management practice(s), a statement of the issue, and an estimate of the cost to repair, replace, reconstruct, or maintain said facilities.

10. (a) If the City determines that the water quality facilities and/or best management practices are not being maintained in good working order and gives written notice to the current Property Owner to repair, replace, reconstruct, or maintain said facilities within a reasonable time, and the property owner fails to comply with the City's notice within the time specified, Property Owner authorizes the City or its agents to enter upon the Property to repair, reconstruct, replace or perform maintenance on said facilities at the Property Owner's expense.

(b) Property Owner further authorizes the City to place a lien for double the amount of said expenses of repair, maintenance or reconstruction against the property.

(c) If the Property Owner fails to pay the City after forty-five (45) days written notice, the Property Owner authorizes the City to collect said expenses from the Property Owner through the appropriate legal action, with the Property Owner to be liable for the reasonable expenses of collection, court costs, and attorney fees.

(d) Property Owner recognizes, however, that this remedy does not obligate the City to maintain or, repair any water quality facilities and/or best management practices or restrict the City from pursuing other or additional legal remedies against the Property Owner.

11. These Covenants shall be binding on the Property Owner's heirs, administrators, executors, successors, and assigns, and any and all subsequent property owners. Upon conveyance of the Property, these Covenants shall transfer to and be binding upon the new property owner and the original Property Owner shall be released from any and all responsibilities and obligations under these Covenants.

12. These Covenants are permanent and shall run with the land.

13. Property Owner will record a plat showing and accurately defining the easements for water quality facilities and best management practices an access easement to these facilities on a survey plat of record. The survey plat must reference the instrument number, where these Covenants are recorded and contain a note that the property owner is responsible for maintaining the facility or practice.

14. Property Owner will record these Covenants with the County Register of Deeds and return the original to the City before the final plat is signed by the City, and before all or any portion of the property is transferred or conveyed.

15. Upon the Property Owner’s satisfaction of all duties set forth in this Covenant and proof of same, the property owner may make application to the City for the return or refund of the bond, letter of credit or cash bond.

16. The Addendum attached hereto is made a part hereof, incorporated herein, and adopted by reference as if set out below.

IN WITNESS WHEREOF, WE HAVE SET OUR HANDS, THIS _____ DAY OF ________________, ____________.

PROPERTY OWNER:

____

CITY of ____________, TENNESSEE

____

By: Mayor

STATE OF TENNESSEE)
COUNTY OF ___________________)

Before me, the undersigned authority, a Notary Public at Large of the State of Tennessee, personally appeared ______________________, the property owner, with whom I am personally acquainted, and who, upon oath, executed the foregoing instrument for the purposes therein contained.

WITNESS my hand and official seal at office in ____________ County, Tennessee this the _ day of ________________, 2___.

NOTARY PUBLIC

My Commission Expires:

STATE OF TENNESSEE)
COUNTY OF ______________)

Before me, the undersigned authority, a Notary Public at Large of the State of Tennessee, personally appeared _______________________, with whom I am personally acquainted, and who, upon oath, executed the foregoing instrument for the purposes therein contained, and who further acknowledged that he or she is the ______ ___________ of the ___________(property owner)_________ and is authorized by _____ ______(property owner)_________ to execute this instrument on behalf of same.

WITNESS my hand and official seal at office in _______________ County, Tennessee this the _ day of ________________, 2___.

NOTARY PUBLIC

My Commission Expires:

STATE OF TENNESSEE)
COUNTY OF ________________)

Before me, the undersigned authority, a Notary Public at Large of the State of Tennessee, personally appeared ________________, with whom I am personally acquainted, and who, upon oath, executed the foregoing instrument for the purposes therein contained, and who further acknowledged that he or she is the Mayor of Knox County, Tennessee and is authorized by _____________ County, Tennessee to execute this instrument on its behalf.

WITNESS my hand and official seal at office in, Tennessee this the . day of _____ __________, 2___.

NOTARY PUBLIC
My Commission Expires:

APPROVED AS TO LEGAL FORM:

_______________________ __________________
Law Director Date

This page left intentionally blank

APPENDIX F

Policies Specific to the City of Bristol, TN

#	Date	Policy Statement	Relevant Section of Manual
1	Nov 2007	WQv Reduction #2 (the Managed Open Space Preservation Reduction) cannot be used within the City of Bristol, TN.	Chap 5 Section 5.2

This page left intentionally blank

APPENDIX G

Policies Specific to the City of Elizabethton, TN

#	Date	Policy Statement	Relevant Section of Manual
1	Nov 2007	WQv Reduction #2 (the Managed Open Space Preservation Reduction) cannot be used within the City of Elizabethton, TN.	Chap 5 Section 5.2

This page left intentionally blank

APPENDIX H

Policies Specific to the City of Johnson City, TN

#	*Date*	*Policy Statement*	*Relevant Section of Manual*

This page left intentionally blank