2004 Connecticut Stormwater Quality Manual

by
The Connecticut Department of Environmental Protection

79 Elm Street • Hartford, Connecticut 06106

Printed on recycled paper, 30% post consumer content.

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Book Production by the DEP Bureau of Water Management, Inland Water Resources Division

The Connecticut Stormwater Quality Manual is available on-line in
Adobe Acrobat (pdf) format.
http://dep.state.ct.us

Funded in part by the CT DEP through a
US EPA Clean Water Act section 319 grant
administered by the CT DEP.

Acknowledgements

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Table of Contents

Volume 1: Background

Chapter 1

Introduction

Chapter 2

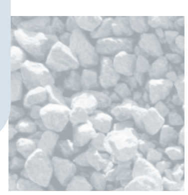
Why Stormwater Matters: The Impacts of Urbanization

Chapter 3

Preventing and Mitigating Stormwater Impacts

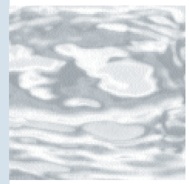
Chapter 4

Site Planning and Design



Chapter 5

Source Control Practices and Pollution Prevention



Volume 1I: Design

Chapter 6

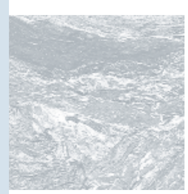
Introduction to Stormwater Treatment Practices

Chapter 7

Hydrologic Sizing Criteria for Stormwater Treatment Practices

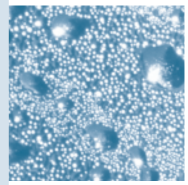
Chapter 8

Selection Criteria for Stormwater Treatment Practices



Chapter 9

Developing a Site Stormwater Management Plan



Chapter 10

Stormwater Retrofits

Chapter 11

Stormwater Treatment Practice Design Guidance

Appendices

Chapter 1
Introduction to the Stormwater Quality Manual

Volume 1: Background

Chapter 1 Introduction

1.1 Purpose of the Manual

The purpose of this Manual is to provide guidance on the measures necessary to protect the waters of the State of Connecticut from the adverse impacts of post-construction stormwater runoff. The guidance provided in this Manual is applicable to new development, redevelopment, and upgrades to existing development. The Manual focuses on site planning, source control and pollution prevention, and stormwater treatment practices. Related topics such as erosion and sediment control, stormwater drainage design and flood control, and watershed management are addressed in the Manual as secondary considerations. The Manual does not address agricultural runoff. Additional information on these topics can be found in other related guidance documents listed at the end of this chapter.

1.2 Users of the Manual

The Connecticut Department of Environmental Protection intends this Manual for use as a planning tool and design guidance document by the regulated and regulatory communities involved in stormwater quality management in the State of Connecticut. The Manual provides uniform guidance for developers and engineers on the selection, design, and proper application of stormwater Best Management Practices (BMPs). The Manual will also assist local and state government officials (i.e., town engineers, planners, Planning and Zoning Commissions, Conservation Commissions, Inland Wetlands Commissions, and Connecticut State agencies) design and review projects in a technically sound and consistent manner.

The information and recommendations in this Manual are provided for guidance and are intended to augment, rather than replace, professional judgement. The design practices described in this Manual should be implemented by individuals with a demonstrated level of professional competence, such as professional engineers licensed to practice in the State of Connecticut. Design engineers, as well as those responsible for operation and maintenance, are ultimately responsible for the long-term performance and success of these practices. However, the use of this Manual is not restricted to engineers or technical professionals. It is also intended to be used by other individuals involved in stormwater and land use management for reviewing and recommending practices contained in the Manual.

1.3 Organization of the Manual

The Manual is organized into two volumes, both contained in a single, comprehensive document. The organization of the Manual generally follows the recommended stormwater management planning process, which emphasizes preventive measures such as site planning and alternative site design, source controls, and pollution prevention over end-of-pipe structural controls.

Volume I provides an overview of the stormwater problem, approaches for preventing and mitigating stormwater impacts, and a description of site planning and source control practices for pollution prevention. The subsequent chapters in Volume I include:

***Chapter Two* – Why Stormwater Matters: The Impacts of Urbanization**

This chapter introduces the concept of urban stormwater runoff and its impact on watershed hydrology, water quality, and ecology. Chapter Two summarizes why stormwater management measures are necessary to protect receiving waters from the adverse impacts of uncontrolled stormwater runoff.

***Chapter Three* – Approaches for Preventing and Mitigating Stormwater Impacts**

Chapter Three presents an overview of approaches for preventing and mitigating stormwater impacts through site planning and pollution prevention, stormwater quantity controls, construction erosion and sedimentation controls, and post-construction stormwater quality management.

***Chapter Four* – Site Planning and Design**

Chapter Four addresses site planning concepts such as alternative site design and Low Impact Development. These techniques can be incorporated into the design of new projects to reduce or disconnect impervious surfaces and retain and infiltrate stormwater on-site, thereby eliminating or reducing the need for structural stormwater quality controls.

***Chapter Five* – Source Control Practices and Pollution Prevention**

Chapter Five describes source control and pollution prevention practices to limit the generation of stormwater pollutants at their source. This chapter focuses on common municipal, residential, commercial, and industrial practices applicable to new and existing development, such as street and parking lot sweeping, roadway deicing and salt storage, storm drainage system maintenance, illicit discharge detection and elimination, commercial and industrial pollution prevention, and lawn care and landscaping practices.

Volume II provides technical guidance on the selection, design, construction, and maintenance of structural stormwater treatment practices. Volume II also addresses procedures for developing a site stormwater management plan, and design issues associated with stormwater retrofits for existing development. Volume II includes the following chapters:

***Chapter Six* – Introduction to Stormwater Treatment Practices**

Chapter Six introduces structural stormwater treatment practices that can be used alone as primary treatment, as pretreatment or supplemental treatment practices, or in combination (i.e., treatment train approach). This chapter also describes general categories of recently developed, emerging, and potential future stormwater treatment devices and technologies, as well as criteria for evaluating the performance and applicability of new treatment practices.

***Chapter Seven* – Hydrologic Sizing Criteria for Stormwater Treatment Practices**

Chapter Seven explains the procedures and applicability of sizing criteria for structural stormwater treatment practices to meet pollutant reduction, groundwater recharge and runoff volume reduction, and peak flow control requirements. This chapter also includes guidance on the design of stormwater bypass structures and sizing examples for various types of stormwater treatment practices.

***Chapter Eight* – Selection Criteria for Stormwater Treatment Practices**

Chapter Eight provides guidance on selecting appropriate structural stormwater treatment practices for a development site based on the requirements and needs of the site. This chapter includes a recommended selection process and selection criteria.

***Chapter Nine* – Developing a Site Stormwater Management Plan**

Chapter Nine describes how to prepare a site stormwater management plan for review by local and state regulatory agencies. The chapter includes a recommended plan format and contents, and a completeness checklist for use by the plan preparer and reviewer.

***Chapter Ten* – Stormwater Retrofits**

Chapter Ten describes techniques for retrofitting existing developed sites to improve or enhance the water quality mitigation functions of the sites. Chapter Ten also discusses the conditions for which stormwater retrofits are appropriate and the potential benefits of stormwater retrofits.

***Chapter Eleven* – Design Guidance for Stormwater Treatment Practices**

Chapter Eleven provides detailed technical design guidance for each of the stormwater treatment practices introduced in Chapter Six. This chapter includes guidance on the design, construction, and maintenance of these practices, as well as summary information on selection and sizing criteria addressed in previous chapters.

Appendices

Appendices containing supplemental information on the design, construction, and maintenance of structural stormwater management practices are included at the end of Volume II. A glossary of terms used in the Manual is also provided in Appendix F.

While providing detailed guidance on a number of recommended stormwater management practices and related topics, this Manual is not an exhaustive reference on each topic and does not address all aspects of stormwater management. Additional technical guidance can be found in numerous other documents, many of which are referenced in this Manual. References and recommended additional sources of information are listed at the end of each chapter.

1.4 Regulatory Basis and Use of the Manual

This Manual is intended for use as a guidance document to assist developers and the regulated community in complying with existing local, state, and federal laws and regulations. The Manual itself has no independent regulatory authority. Rather, it establishes guidelines that are implemented through a framework of existing laws and regulations. Although this Manual is non-regulatory in scope, it provides the technical basis for a comprehensive, statewide stormwater quality management strategy, including the consistent application of stormwater management practices throughout the state.

1.5 Relationship of the Manual to Federal, State, and Local Programs

The Connecticut Department of Environmental Protection (DEP) historically has been a national leader in developing and implementing water quality protection programs and policies. A number of federal and state regulatory programs are currently in place for stormwater quality management and water resource protection in the state. Consistent with a long-established tradition of home-rule-style government exerted by municipal authorities, many of these programs are implemented at the local level through local zoning, subdivision, and inland wetlands and watercourses regulations and ordinances. In addition, the State of Connecticut has been delegated authority from the federal government to implement federal regulations that pertain to water resources protection. **Table 1-1** summarizes existing regulatory programs that address management of stormwater discharges in Connecticut. Descriptions of these programs and their relationship to this Manual are found in Section 1.5.2.

1.5.1 Federal Programs

Clean Water Act

The Federal Water Pollution Control Act of 1948, the first major federal legislation governing pollution of the nation's surface waters (33 U.S.C. 1251-1387), was significantly amended in 1972 (P.L. 92-500) and then again in 1977 when it became commonly known as the Clean Water Act (CWA) of 1977 (P.L. 95-217). The CWA was subsequently amended under the Water Quality Act of 1987 (P.L. 100-4). There are four primary sections of the CWA that relate to stormwater discharges:

- *Section 303 – Water Quality Standards and Implementation Plans*
- *Section 319 – Nonpoint Source Management Program*
- *Section 401 – Water Quality Certification*
- *Section 402 – National Pollutant Discharge Elimination System (NPDES)*

Under Section 303 of the CWA, states are required to adopt surface water quality standards, subject to review and approval by the U.S. EPA, and identify surface waters that do not meet these water quality standards following the installation of minimum required pollution control technology for point sources discharging to surface water bodies. These impaired water bodies must be ranked by the states and a Total Maximum Daily Load (TMDL) must be established for the pollutant(s) that exceed the water quality standards. A TMDL both specifies a maximum amount of pollutant that the surface water body can receive and allocates that amount, or load, among point and nonpoint sources, including stormwater discharges.

The Nonpoint Source Management Program was established under Section 319 of the CWA of 1987. Section 319 addresses the need for federal guidance and assistance to state and local programs for controlling nonpoint sources of pollution, including stormwater runoff. Under Section 319, states, territories and Indian Tribes receive federal grant money to support various activities that address nonpoint source pollution control. These activities include technical and direct financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the effectiveness of specific nonpoint source implementation projects.

Section 401 of the CWA requires applicants for a federal license or permit to obtain a certification or waiver from the state water pollution control agency (DEP, or EPA for Indian reservation lands) for any activity which may result in a discharge into navigable waters of the state, including wetlands, watercourses, and natural and man-made ponds. This waiver certifies that the discharge will comply with the applicable provisions of the CWA and Connecticut's Water Quality Standards. Examples of federal licenses and permits for which water quality certification is required include U.S. Army Corps of Engineers Section 404 dredge and fill permits, Coast Guard bridge permits, and Federal Energy Regulatory Commission permits for hydropower and gas transmission facilities.

The NPDES program was established under Section 402 of the CWA and specifically targets point source discharges by industries, municipalities, and other facilities that discharge directly into surface waters. Stormwater discharges are addressed under the NPDES Stormwater Program. This two-phased national program targets non-agricultural sources of stormwater discharges that may adversely affect surface water quality. The NPDES permitting program is administered in Connecticut by DEP through a series of permits as outlined in **Table 1-1**. Phase I of the NPDES Stormwater Program was developed under the 1987 amendments to the CWA and regulates stormwater discharges from:

- *"Medium" and "large" municipal separate storm sewer systems (MS4s) located in incorporated places or counties with populations of 100,000 or more; and*
- *Eleven categories of industrial activity, one of which is construction activity that disturbs five or more acres of land.*

Phase II of the program expands the scope of the regulated discharges to include:

- *Certain regulated "small" MS4s; and*
- *Construction activity disturbing between one and five acres of land (i.e., small construction activities).*

The Phase II Final Rule was published in December 1999. DEP issued a General Permit in 2004 to address small municipalities. At the time of writing, DEP was in the process of developing a General Permit for the Connecticut Department of Transportation and other state and federal facilities with significant drainage systems and stormwater discharges. Stormwater discharges associated with construction activities between one and five acres are regulated by DEP through a coordinated effort with municipalities under the Connecticut Erosion and Sedimentation Control Act.

Coastal Zone Act Reauthorization Amendments

Section 6217 of the Coastal Zone Act Reauthorization Amendments (CZARA) of 1990 (16 U.S.C. §1455b) is designed to address the problem of nonpoint source pollution in coastal waters. Under Section 6217, states and territories with approved Coastal Zone Management Programs, including Connecticut, are required to develop Coastal Nonpoint Source Pollution Control Programs or face funding sanctions in both their coastal programs and their nonpoint programs established under Section 319 of the Clean Water Act. The program must describe how the state or territory will implement management measures to reduce or eliminate nonpoint source pollution, including stormwater runoff, to coastal waters. These management measures must conform to those described in the U.S. EPA publication *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters.*

1.5.2 State Programs

Connecticut Clean Water Act

The Connecticut Clean Water Act (CCWA) of 1967 (P.A. 67-57) launched Connecticut's modern water pollution control program. Under the CCWA, as amended, DEP has the regulatory authority to:

- *Abate, prevent or minimize all sources of water pollution, including nonpoint sources*
- *Develop state water quality standards*
- *Permit discharges, including stormwater discharges, to waters of the state*
- *Establish enforcement tools for pollution abatement and prevention*

This statute (Chapter 446k of the Connecticut General Statutes (CGS)) forms the authority for the DEP Bureau of Water Management's Permitting and Enforcement Division (PED) to regulate discharges to surface waters, ground waters, and Publicly Owned Treatment Works (POTWs). Discharges to surface waters are regulated by DEP under both the CCWA and the federal NPDES Program, because Connecticut has been delegated authority to implement the federal NPDES Program. Consequently, stormwater discharges are regulated under a series of general permits based on the type of activity generating the discharge. The general permit program is authorized under CGS §22a-430b and is designed to authorize similar minor stormwater discharges by one or more applicants. The regulated sources are divided into four major categories:

Commercial Activities: This general permit applies to discharges from any conveyance which is used for collecting and conveying stormwater and which is directly related to retail, commercial, and/or office services whose facilities occupy 5 acres or more of contiguous impervious surface and which are described in the SIC Codes 50's and 70's.

Industrial Activities: This general permit applies to discharges from any conveyance which is used for collecting and conveying stormwater and which is directly related to manufacturing, processing or material storage areas at designated categories of industrial facilities.

Construction Activities: This general permit applies to discharges of stormwater and dewatering wastewaters from construction activities which include, but are not limited to, clearing, grading, and excavating and which result in the disturbance of 5 or more acres of total land area on a site. As described above, under Phase II of the NPDES Stormwater Program, construction activities disturb-

Table 1-1 Existing Stormwater Management Programs in Connecticut

Program/ DEP Contact	Programs Goals	Stormwater Regulation	Regulates Quantity	Regulates Quality	State or Local Regulations (Authorizing Statute)	Regulation of New or Existing Facilities[1]
Commercial General Permit PED Stormwater (860) 424-3018	Regulates stormwater discharges from commercial activity	Requires permits from a commercial activity with 5 or more acres of contiguous impervious surfaces	No	Yes	State (CGS §§22a-416 through 22a-438)	Both
Industrial General Permit PED Stormwater (860) 424-3018	Regulates stormwater discharges from industrial activities	Requires permits for facilities having a stormwater discharge associated with industrial activity	No	Yes	State (CGS §§22a-416 through 22a-438)	Both
Construction General Permit PED Stormwater (860) 424-3018	Regulates stormwater discharges from construction activity	Requires permits from construction activities disturbing more than 5 total acres land area (projects disturbing 1 to 5 acres regulated at the local level under NPDES Phase II)	No	Yes	State (CGS §§22a-416 through 22a-438)	Both
Phase II General Permits PED Stormwater (860) 424-3018	Regulates stormwater discharges from municipal, state, and other designated stormwater drainage systems in urbanized areas	Requires municipalities and other entities to develop and implement a stormwater management program consisting of minimum control measures	Yes	Yes	State (CGS §§22a-416 through 22a-438)	Both
Inland Wetlands and Watercourses Act IWRD (860) 424-3019	Protects and regulates activities in inland wetlands, watercourse, and adjacent areas	Considers impacts to wetlands from stormwater or stormwater-related activities	Yes	Yes	State and Local (CGS §§22a-36 though 22a-45a)	Both
Erosion and Sediment Guidelines IWRD (860) 424-3019	Provides guidance on erosion controls	Guidelines for control of stormwater during construction	Yes	Yes (sediment)	State and Local (CGS §§22a-325 through 22a-329)	New
Flood Management IWRD (860) 424-3019	Regulates state actions in floodplains and changes in drainage patterns	Requires careful planning and siting of development projects and modifications to flood control facilities	Yes	Yes	State (CGS §§25-68b through 25-68h)	Both
Stream Channel Encroachment program IWRD (860) 424-3019	Regulates activities in certain floodplains	Considers impacts to wetlands and watercourses from storm water or stormwater-related activities	Yes	Yes	State (CGS §§22a-342 through 22a-349a)	Both
401 Water Quality Certification IWRD (860) 424-3019	Regulates activities which require a federal license or permit for discharge into navigable waters of the state	Requires certification from DEP that the discharge will comply with the Federal Water Pollution Control Act and Connecticut Water Quality Standards	No	Yes	State/Federal (33 USC 1341)	Both
Water Diversion IWRD (860) 424-3019	Regulates withdrawal and use of groundwater and surface waters of the state, including stormwater diversions	Requires permitting for any activity that causes, allows, or results in the withdrawal from or the alteration, modification, or diminution of the instantaneous flow of water, including stormwater	Yes	Yes	State (CGS §§22a-365 through 22a-379a)	Both
Dam Safety IWRD (860) 424-3706	Regulates construction, alteration, and repair of dams, including stormwater impoundments	Requires registration and potentially permit approval/inspection for new stormwater impoundments (ponds, wetlands, infiltration basins, etc.)	No	No	State (CGS §§22a-401 through 22a-411)	Both

Table 1-1 Existing Stormwater Management Programs in Connecticut *(con't)*

Program/ DEP Contact	Programs Goals	Stormwater Regulation	Regulates Quantity	Regulates Quality	State or Local Regulations (Authorizing Statute)	Regulation of New or Existing Facilities[1]
Coastal Management Act OLISP (860) 424-3034	Protects coastal resources and supports water-dependent uses	Regulates development that impacts coastal water and resources	Yes	Yes	State and Local (CGS §§22a-90 through 22a-112)	Both
Tidal Wetlands Act OLISP (860) 424-3034	Requires permits for dredging, draining, or filling within tidal wetlands	Discourages direct stormwater discharges	Yes	Yes	State (CGS §§22a-28 through 22a-35)	Both
Structures Dredging and Fill Act OLISP (860) 424-3034	Requires permits for structures, dredging, or fill in tidal, coastal, or navigable waters	Discourages direct stormwater discharges	Yes	Yes	State (CGS §§22a-359 through 22a-363f)	Both
Nonpoint Source Management Program PSD (860) 424-3020	Coordinates statewide efforts to prevent and manage nonpoint source pollution	Relies on existing regulations in place at federal, state, and local level	No	No	State	Both
Aquifer Protection Program PSD (860) 424-3020	Addresses potential groundwater contamination through various programs to ensure safe drinking water supplies	Management plans may include stormwater controls	No	Yes	State and Local (CGS §§22a-354a through 22a-354b)	Both
Source Water Assessment Program BWM/DPH (860) 424-3704	Assessment and protection of public drinking water supply sources	Requires assessment of delineated protection areas of potential sources of contamination. Relies primarily on existing regulations.	No	No	State and Federal	Both
Underground Injection Control Program BWM (860) 424-3018	Prohibits the use of Class V wells and limits the use of UIC drywells in existing or potential groundwater drinking supply areas	Requires safeguards for infiltration of stormwater in areas with high potential for spills and groundwater drinking supply areas	No	Yes	State and Federal	Both
Public Health Code – Sanitation of Watersheds DPH	Protects public water supply sources	Regulates stormwater discharges within 100 feet of an established watercourse within public water supply watersheds or groundwater aquifer recharge areas	Optional	Yes	PHC 19-13-B32i	New
Municipal Planning and Zoning Authorities	Reviews site development plans and protects environmental resources	Considers impacts to receiving waters	Optional	Optional	Local	Both

[1]Refers to whether the program primarily applies to newly constructed facilities or new development (New), existing facilities or development (Existing), or both.

PED – Permitting and Enforcement Division, IWRD – Inland Water Resources Division, OLISP – Office of Long Island Sound Programs, PSD – Planning and Standards Division, BWM – Bureau of Water Management, DPH – Department of Public Health, CGS – Connecticut General Statutes ing between one and five acres are also regulated by DEP through a coordinated effort with municipalities under the Connecticut Erosion and Sedimentation Control Act.

Municipal Separate Storm Sewer Systems (MS4s): This general permit regulates discharges of stormwater from small MS4s and other similar facilities located in urbanized areas. Separate general permits address stormwater discharges from small municipalities and other state and public facilities, as well as the Connecticut Department of Transportation.

Inland Wetlands and Watercourses Act

The Inland Wetlands and Watercourses Act of 1972, as amended, establishes authority for DEP and municipalities to adopt programs regulating construction and other activities affecting inland wetlands and watercourses, including impacts due to stormwater or stormwater-related activities. The Wetlands Management Section of the DEP Inland Water Resources Division (IWRD) has responsibility for overseeing implementation of the Act and directly regulates the activities of Connecticut state agencies that are located in, or may affect, inland wetlands and watercourses. As discussed in more detail below, local inland wetland agencies are responsible for regulating private and municipal work located in, or affecting, wetlands or watercourses within each Connecticut municipality.

Soil Erosion and Sediment Control Act

The Soil Erosion and Sediment Control Act (CGS §§22a- 325 to 22a-329, inclusive) requires that the Council on Soil and Water Conservation develop guidelines for soil erosion and sediment control on land being developed. The latest version of these guidelines was released in April of 2002. The goal of the guidelines is to reduce soil erosion from stormwater runoff, minimize nonpoint sediment pollution from land being developed, and conserve and protect the land, water, air and other environmental resources of the state.

Flood Management Certification

Under CGS §§25-68b through 25-68h, inclusive, any state agency proposing an activity within or affecting a floodplain or impacting natural or man-made storm drainage facilities must submit a flood management certification application to DEP.

Stream Channel Encroachment

Stream channel encroachment lines have been established for approximately 270 linear miles of riverine floodplain throughout Connecticut. Under CGS §§22a-342 through 22a-349a, DEP IWRD regulates the placement of encroachments and obstructions riverward of these encroachment lines. Any activity that permanently alters the character of the floodplain or watercourse within these areas, including activities generating stormwater discharges, is subject to approval by DEP.

401 Water Quality Certification

Applicants for a federal license or permit for activities that may result in a discharge into navigable waters of the state, including stormwater discharges, must submit a water quality certification application to DEP.

Water Diversion Policy Act

The Water Division Policy Act of 1982 (P.A. 82-402, as amended) grants the DEP IWRD limited authority to regulate the withdrawal and use of groundwater and surface waters of the state, including stormwater diversions. Under CGS §§22a-365 through 22a-379a, permitting is required for any activity that causes, allows, or results in the withdrawal from, or the alteration, modification, or diminution of, the instantaneous flow of water. Diversions must be consistent with other state policies that deal with long-range planning, management and use of the water resources of the state, including the State Plan for Conservation and Development, Water Quality Standards, Flood Management Act, Water Supply Planning Process, Inland Wetlands and Watercourses Act, Aquifer Protection Act, and Endangered Species Act.

Dam Safety Program

The Dam Safety Section of the DEP IWRD is responsible for administration and enforcement of Connecticut's dam safety laws under CGS §§22a-401 through 22a-411, inclusive. The Dam Safety Section regulates the construction, alteration, repair, and removal of dams, including stormwater impoundments through the use of embankments such as stormwater retention/detention ponds, stormwater wetlands, and infiltration basins. Registration with the Dam Safety Section is required for all new stormwater impoundments. A dam construction permit may also be required if the structure may endanger life or property in the event of failure or breaking away. Structures that pose a significant or high hazard to life or property are also subject to periodic inspections by DEP.

Connecticut Coastal Management Act

The Connecticut Coastal Management Act (CGS §§22a-90 through 22a-112, inclusive) establishes goals and policies for the protection of coastal resources. Under CGS §22a-98, the Commissioner of DEP must coordinate all regulatory programs under his jurisdiction with permitting authorities in the coastal area, including those related to wetlands and watercourses, stream channel encroachment, and the erection of structures or placement of fill in tidal, coastal, or navigable waters, to ensure that permits issued under such regulatory authority are consistent with coastal management goals and policies. The coastal area is defined by statute (CGS §22a-94(a)) and encompasses the municipalities listed in Table 1-2. In addition, pursuant to CGS §22a-100(b), each state department, institution, or agency responsible for the primary recommendation or initiation of actions within the coastal boundary which may significantly affect the environment must also ensure that such actions are consistent with coastal management goals and policies and incorporate all reasonable measures mitigating any adverse impacts on coastal resources. The coastal boundary is defined by statute (CGS §22a-94(b)). Adverse impacts on coastal resources are also statutorily defined (CGS §22a-93(15)) and include degrading water quality through the significant introduction into either coastal waters or groundwater supplies of suspended solids, nutrients, toxics, heavy metals, or pathogens, all of which can be contained in stormwater. In addition, degrading water quality through the significant alteration of temperature, pH, dissolved oxygen, or salinity is also included in the statutory definition of adverse impacts, and these impacts can also result from stormwater runoff. Coastal permitting and assistance to municipalities is administered through the DEP Office of Long Island Sound Programs (OLISP).

Tidal Wetlands Act

The Tidal Wetlands Act of 1969 (CGS §§22a-28 through 22a-35, inclusive) gives DEP authority to regulate activities in tidal wetlands. The permitting program administered by OLISP requires that the applicant address possible impacts to coastal resources, including those associated with stormwater runoff, and discourages direct stormwater discharges to tidal wetlands.

Structures, Dredging and Fill Act

The Structures, Dredging, and Fill Act (CGS §§22a-359 through 22a-363f, inclusive) gives DEP the authority to regulate dredging, the erection of structures, and the placement of fill in tidal, coastal or navigable waters of the state waterward of the high tide line. The permitting program administered by OLISP requires that the applicant address possible impacts to coastal resources, including those associated with stormwater runoff, and discourages direct untreated stormwater discharges to tidal, coastal, or navigable waters.

Nonpoint Source Management Programs (pursuant to CWA Section 319 and CZARA Section 6217)

The Connecticut Nonpoint Source Management (NPS) Program is administered by the DEP Bureau of Water Management (BWM) Planning and Standards Division (PSD) and is a network of several federal, state, and local programs. The NPS Program includes all of the components required under Section 319 of the Federal Clean Water Act. It establishes long- and short-term goals for the prevention and management of nonpoint sources of pollution, including those associated with urban runoff and stormwater. EPA defines NPS pollution as that which is "caused by diffuse sources that are not regulated as point sources and are normally associated with precipitation and runoff from the land or percolation." EPA approved Connecticut's upgraded Nonpoint Source Management Program in November 1999 (see Nonpoint Source Management Program at http://www.dep.state.ct.us/wtr/nps/npsmgtpl.pdf).

As described in the discussion of federal programs above, Section 6217 of the 1990 CZARA requires the development of a Coastal Nonpoint Pollution Control Program (CNPCP) to implement management measures to reduce or eliminate nonpoint source pollution within the coastal boundary. The CNPCP is a networked program administered by OLISP with assistance from BWM and relies on other regulatory programs described in this section including state and local permitting authorities.

Aquifer Protection Area Act

The Aquifer Protection Area Act of 1989 requires the development of aquifer protection land use regulations applicable within DEP-approved aquifer protection areas (areas recharging large public water supply wells). As part of the regulations, issued in 2004, municipalities containing aquifer protection areas are required to adopt regulations, subject to approval by DEP, requiring permitting for all regulated activities within aquifer protection areas. In addition, regulated activities within an aquifer protection area may require a stormwater management plan to assure that stormwater runoff generated by the proposed activity is managed in a manner to prevent pollution of ground water.

Source Water Assessment Program (SWAP)

The Connecticut Source Water Assessment Program (SWAP) was initiated in 1997 in response to the 1996 Amendments to the Federal Safe Drinking Water Act. The Connecticut Department of Public Health (DPH), in partnership with DEP, is responsible for the development of the SWAP, which is designed to assess and protect public drinking water supply sources in the state. The SWAP completes its work based upon an EPA-approved Work Plan dated September 1999. The SWAP includes the delineation of a protection area surrounding the drinking water source, the identification of potential pollution sources within and around the protection area, and the determination of a water supply's susceptibility to contamination. The SWAP will build on existing surface water and wellhead protection programs administered by DPH and DEP. As part of the program, DEP and DPH will recommend a variety of source protection strategies aimed

Table 1-2
Municipalities Within The Coastal Area

Branford	Groton Long Point	Norwich
Bridgeport	Guilford	Old Saybrook
Chester	Hamden	Old Lyme
Clinton	Ledyard	Orange
Darien	Lyme	Preston
Deep River	Madison	Shelton
East Haven	Milford	Stamford
East Lyme	Montville	Stonington (Borough and Town of)
Essex	New London	Stratford
Fairfield	New Haven	Waterford
Fenwick	Noank	West Haven
Greenwich	North Haven	Westbrook
Groton (City and Town of)	Norwalk	Westport

at reducing potential impacts from non-point pollution sources including stormwater runoff to municipalities and water companies. Additional information on the SWAP can be found at http://www.dph.state.ct.us/BRS/WSS/swap_reports. htm.

Underground Injection Control (UIC) Program

The Federal Safe Drinking Water Act established the UIC program to provide safeguards so that injection (or infiltration) wells used for waste disposal do not endanger water quality, especially groundwater drinking sources. In Connecticut, the DEP Water Management Bureau has been given primacy for this program. A well under the UIC Program is any well whose depth is greater than the largest surface dimension (this could include certain infiltration trenches with vertical pipe connections) that is used to discharge waste to the ground. Historically the type of UIC wells used in Connecticut were "Class V" (not hazardous wastes). They were typically drywell-type structures, and were most commonly used for automotive service drains. In Connecticut these types of wells are no longer allowed, and groundwater discharges of wastes other than domestic sewage or clean water are not allowed to the ground in existing or potential groundwater drinking supply area. Stormwater structures such as infiltration drywells or trenches, which are susceptible to spills, leaks, or other chemical releases, especially at industrial or petro-chemical commercial sites, may be considered UIC wells.

Care must be taken to ensure that stormwater drywells or infiltration trenches do not threaten groundwater quality, especially drinking water sources. Later chapters in this Manual provide guidance about sites where the use of stormwater infiltration structures should be avoided due to groundwater quality concerns, and sites where they could be used to recharge stormwater with pretreatment or other safeguards.

Public Health Code – Sanitation of Watersheds

Connecticut Public Health Code §19-13-B32i requires that stormwater discharges terminate at least one hundred feet from an established watercourse located within lands tributary to public drinking water supplies, including both surface and groundwater sources. If such termination is not possible, discharges that terminate within 100 feet of a watercourse require review by the Department of Public Health. Discharges within 100 feet must include adequate flow energy dissipation and must not adversely impact stream quality. This requirement applies to surface drinking water supply watershed areas, approximately 16.5 percent of Connecticut's land area, and to streams tributary to public drinking water supply wells.

1.5.3 Local Programs

State-Mandated Programs

Several of the state programs discussed above require the implementation of municipal regulations and permitting processes, including:

Inland Wetlands and Watercourses Act: CGS §22a-42(c) requires that each municipality establish an Inland Wetlands and Watercourses Agency and local regulations regulating private and municipal work located in or affecting wetlands or watercourses. The regulations must conform to model regulations developed by DEP and contain certain criteria and procedures for application review. The application must address measures to prevent or minimize pollution, including those associated with stormwater runoff.

Erosion and Sediment Control Act: The Erosion and Sediment Control Act requires that municipalities adopt regulations requiring that a soil erosion and sediment control plan be submitted with any application for development within the municipality when the disturbed area of such development is more than one-half acre.

Coastal Management Act/Coastal Site Plan Review: Under the CCMA, coastal municipalities are required to implement Connecticut's Coastal Management Program through their existing planning and zoning authorities. Most activities within the coastal boundary, as defined by DEP according to CGS §22a-94, require municipal Coastal Site Plan Review (CSPR). In this review process, the applicant must describe the proposed project and identify coastal resources in the project area and potential

impacts to those resources. Local planning and zoning authorities must decide whether potential adverse impacts to water quality or other coastal resources are acceptable. A description of stormwater management measures may be required depending on the size of a project and the municipality concerned. CGS §22a-101 allows coastal municipalities to develop Municipal Coastal Programs, which are revisions to plans of conservation and development and zoning regulations to focus on the coastal resources and coastal management issues unique to each town.

Municipal Planning/Zoning: Public Act 91-170 (codified in CGS §8-2(b) and CGS §8-35a) and Public Act 91-395 (codified in CGS §8-23(a)) require that the zoning regulations and plans of conservation and development for any municipality contiguous to Long Island Sound, and the regional plans of development of each region contiguous to Long Island Sound, be made with reasonable consideration for the restoration and protection of the ecosystem and habitat of Long Island Sound. These documents must also contain recommendations and practices to reduce hypoxia, pathogens, toxic contaminants, and floatable debris in Long Island Sound.

Aquifer Protection Act: Under the aquifer protection land use regulations, issued in 2004, municipalities containing aquifer protection areas are directed to adopt regulations requiring local permitting for all regulated activities within aquifer protection areas. In addition, regulated activities within an aquifer protection area may require a stormwater management plan to ensure that stormwater runoff generated by the proposed activity is managed in a manner to prevent pollution of ground water.

Municipal Planning/Zoning

Development projects and other activities subject to approval by municipal planning and zoning authorities are typically subject to review for potential impacts to environmental resources. Depending upon the local regulations, stormwater quantity and/or quality may be regulated. In addition, some municipalities have developed or are considering developing local stormwater quality ordinances.

Additional Information Sources

Watershed Management

Center for Watershed Protection. 2000. *The Practice of Watershed Protection*, Ellicott City, Maryland.

Davenport, T.E. 2002. *The Watershed Project Management Guide*. Lewis Publishers/CRC Press.

U.S. Environmental Protection Agency, Office of Water. 2001. *Protecting and Restoring America's Watersheds: Status, Trends, and Initiatives in Watershed Management*. EPA-840-R-00-001.

Agricultural Runoff

Connecticut Department of Environmental Protection and U.S. Department of Agriculture, Natural Resources Conservation Service. 1993. *Guidelines for Protecting Connecticut's Water Resources.*

U.S. Environmental Protection Agency, Office of Water. 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters.*

U.S. Department of Agriculture, Natural Resource Conservation Service. *National Handbook of Conservation Practices.*

Drainage Design and Flood Control

Connecticut Department of Transportation (DOT). 2000. *Connecticut Department of Transportation Drainage Manual.*

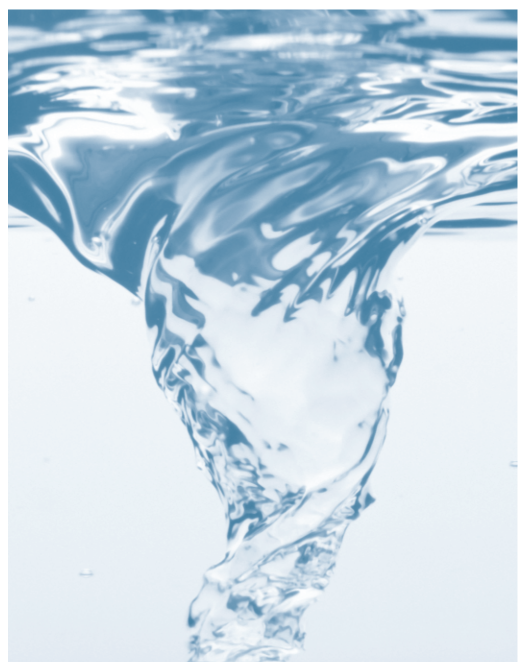
Natural Resource Conservation Service (formerly Soil Conservation Service). 1986. Urban Hydrology for Small Watersheds, TR-55.

Water Environment Federation (WEF) and American Society of Civil Engineers (ASCE). 1992. *Design and Construction of Urban Stormwater Management Systems (Urban Runoff Quality Management (WEF Manual of Practice FD-20 and ASCE Manual and Report on Engineering Practice No. 77).*

Erosion and Sediment Control

Connecticut Council on Soil and Water Conservation and the Connecticut Department of Environmental Protection. 2002. *2002 Connecticut Guidelines for Soil Erosion and Sediment Control, DEP Bulletin 34.*

Chapter 2
Why Stormwater Matters: The Impacts of Urbanization



Volume 1: Background

Chapter 2

Why Stormwater Matters: The Impacts of Urbanization

2.1 What is Urban Stormwater Runoff?

Stormwater runoff is a natural part of the hydrological cycle, which is the distribution and movement of water between the earth's atmosphere, land, and water bodies. Rainfall, snowfall, and other frozen precipitation send water to the earth's surfaces. Stormwater runoff is surface flow from precipitation that accumulates in and flows through natural or man-made conveyance systems during and immediately after a storm event or upon snowmelt. Stormwater runoff eventually travels to surface water bodies as diffuse overland flow, a point discharge, or as groundwater flow. Water that seeps into the ground eventually replenishes groundwater aquifers and surface waters such as lakes, streams, and the oceans. Groundwater recharge also helps maintain water flow in streams and wetland moisture levels during dry weather. Water is returned to the atmosphere through evaporation and transpiration to complete the cycle. A schematic of the hydrologic cycle is shown in **Figure 2-1**.

Traditional development of the landscape with impervious surfaces such as buildings, roads, and parking lots, as well as storm sewer systems and other man-made features, alters the hydrology of a watershed and has the potential to adversely affect water quality and aquatic habitat. As a result of development, vegetated and forested land that consists of pervious surfaces is largely replaced by land uses with impervious surfaces. This transformation increases the amount of stormwater runoff from a site, decreases infiltration and groundwater recharge, and alters natural drainage patterns. This effect is shown schematically in **Figure 2-2.** In addition, natural pollutant removal mechanisms provided by on-site vegetation and soils have less opportunity to remove pollutants from stormwater runoff in developed areas. During construction, soils are exposed to rainfall, which increases the potential for erosion and sedimentation. Development can also introduce new sources of pollutants from everyday activities associated with residential, commercial, and industrial land uses. The development process is known as "urbanization." Stormwater runoff from developed areas is commonly referred to as "urban stormwater runoff."

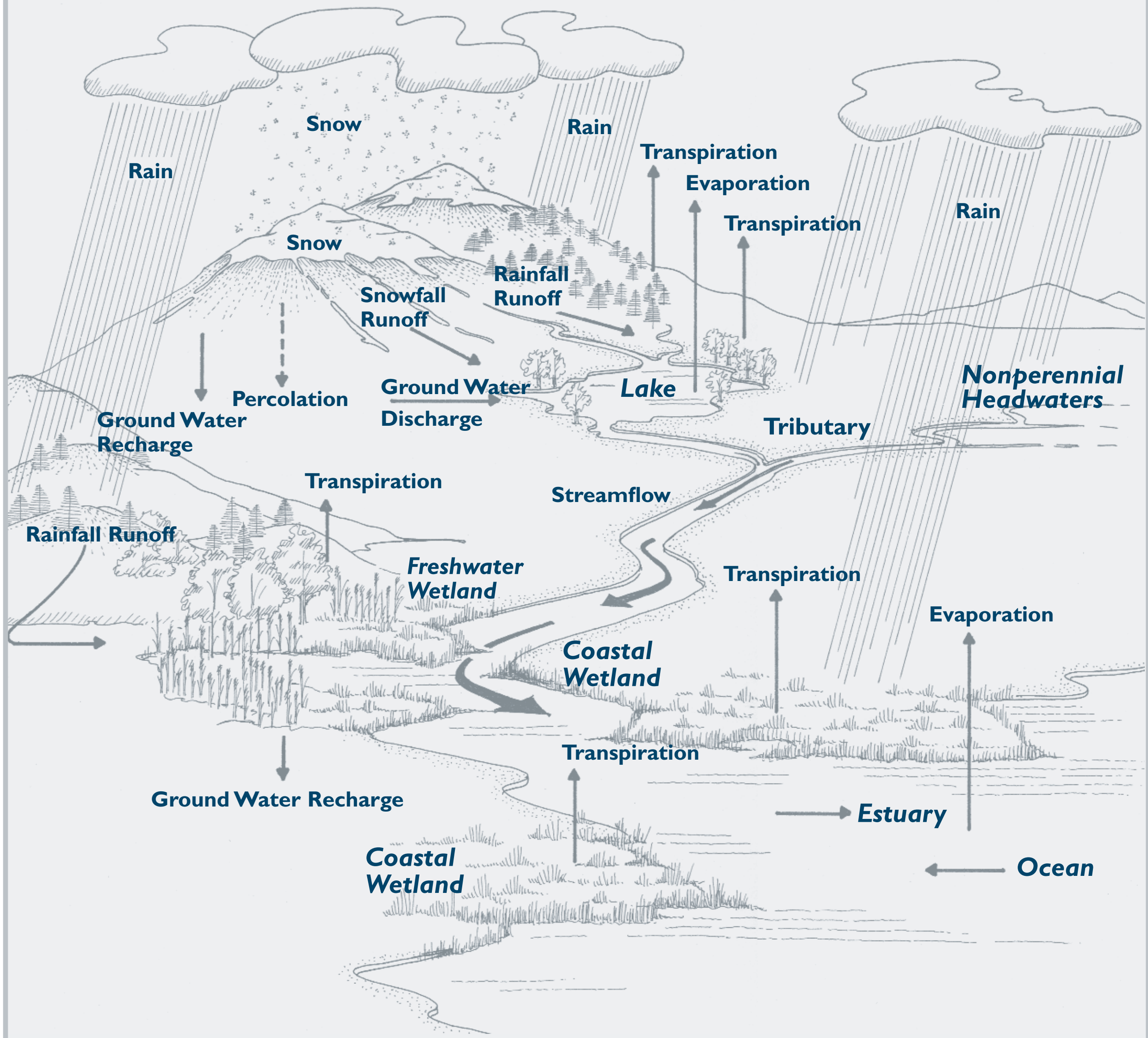
Urban stormwater runoff can be considered both a point source and a nonpoint source of pollution. Stormwater runoff that flows into a conveyance system and is discharged through a pipe, ditch, channel, or other structure is considered a point source discharge under EPA's National Pollutant Discharge Elimination System (NPDES) permit program, as administered by DEP. Stormwater runoff that flows over the land surface and is not concentrated in a defined channel is considered nonpoint source pollution. In most cases stormwater runoff begins as a nonpoint source and becomes a point source discharge (MADEP, 1997). Both point and nonpoint sources of urban stormwater runoff have been shown to be significant causes of water quality impairment (EPA, 2000).

According to the draft 2004 Connecticut list of impaired waters ("303(d)") list prepared pursuant to Section 303(d) of the Federal Clean Water Act), urban runoff and stormwater discharges were a significant cause of aquatic life and contact recreation (e.g. swimming and boating) impairment to approximately one-quarter of the state's 893 miles of major rivers and streams. Urban runoff is also reported as a contributor to excessive nutrient enrichment in numerous lakes and ponds throughout the state, as well as a continued threat to estuarine waters and Long Island Sound (EPA, 2001). **Table 2-1** summarizes impaired Connecticut water bodies (i.e., those not meeting water quality standards) for which urban runoff, stormwater discharges, or other wet-weather sources are suspected causes of impairment (DEP, 2004 draft). This list does not include water bodies impaired as a result of other related causes such as combined sewer overflows (CSOs) and agricultural runoff or unknown sources.

Impervious cover has emerged as a measurable, integrating concept used to describe the overall health of a watershed. Numerous studies have documented the cumulative effects of urbanization on stream and watershed ecology (See, e.g., Schueler et al., 1992; Schueler, 1994; Schueler, 1995; Booth and Reinelt, 1993, Arnold and Gibbons, 1996; Brant, 1999; Shaver and Maxted, 1996). Research has shown that when impervious cover in a watershed reaches between 10 and 25 percent, ecological stress becomes clearly apparent. Beyond 25 percent, stream stability is reduced, habitat is lost, water quality becomes degraded, and biological diversity decreases (NRDC, May 1999). **Figure 2-3** illustrates this effect.

To put these thresholds into perspective, typical total imperviousness in medium density, single-family home residential areas ranges from 25 to nearly 60 percent (Schueler, 1995). **Table 2-2** indicates typical percentages of impervious cover for various land uses in Connecticut and the Northeast

Figure 2-1 Hydrologic Cycle



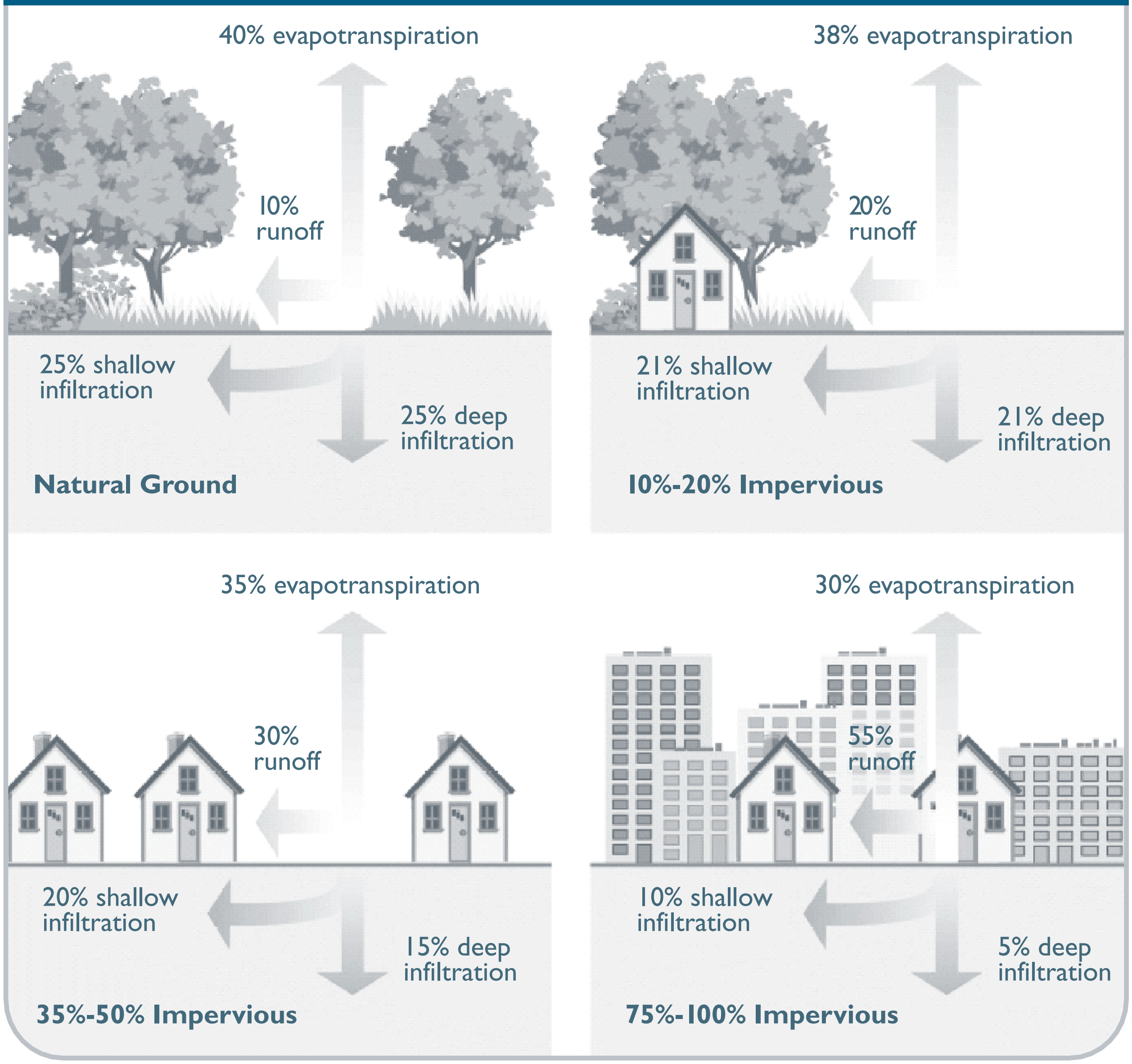
Source: National Water Quality Inventory, U.S. EPA, 1998.

Table 2-1 Connecticut Water Bodies Impaired by Urban Stormwater Runoff

Major Basin	Water Body	Major Basin	Water Body
Pawcatuck River Basin	Pawcatuck River Estuary	Thames River Basin	Thames River Estuary Eagleville Brook Quinebaug River
Southeast Coastal Basins	Fenger Brook Stonington Harbor West and Palmer Coves Mumford Cove Alewife Cove Long Island Sound East Niantic Bay: upper bay, river and offshore Wequetequock Cove Copps Brook Estuary/Quiambog Cove Mystic River Estuary Pequonock River Estuary/Baker Cove Jordan Cove Pattagansett River Estuary Fourmile River	Housatonic River Basin	Housatonic River Housatonic River Estuary Hitchcock Lake Ball Pond Still River Kenosia Lake Padanaram Brook Sympaug Brook Naugatuck River Naugatuck River, West Branch Steele Brook Mad River Hop Brook Lake
Southwest Coastal Basins	Bridgeport Harbor Blackrock Harbor Sherwood Mill Pond/Compo Cove Westcott Cove Greenwich Cove Byram Beach Captain Harbor Rooster River Ash Creek Upper/Lower Mill Ponds Sasco Brook/Estuary Saugatuck River Estuary Norwalk River and Harbor Ridgefield Brook Five Mile River/Estuary Darien Cove Holly Pond/Cove Harbor Stamford Harbor Cos Cob Harbor Byram River/Estuary Long Island Sound West: Southport Harbor	South Central Coastal Basins	Oyster River Tributary Madison Beaches Island Bay/Joshua Cove Thimble Islands Plum Bank Indiantown Harbor Patchogue River Clinton Harbor Guilford Harbor Cedar Pond Linsley Pond Branford Harbor Hanover Pond Quinnipiac River New Haven Harbor Tenmile River Sodom Brook Harbor Brook Wharton Brook Mill River Edgewood Park Pond West River Milford Harbor/Gulf Pond Long Island sound Central Menunnketesuck River Hammonasset River Indian River Hammock Riber Branford Supply Pond West Pisgah River Pine Gutter Brook Allen Brook
Connecticut River Basin	Pequabuck River Birge Pond Pine Lake Park River, South Branch Batterson Park Pond Piper Brook Trout Brook Park River, North Branch Hockanum River Union Pond Mattabesset River Willow Brook Pocotopaug Creek Connecticut River Estuary	Crystal Lake John Hall Brook Little Brook Spruce Brook Coles Brook Miner Brook Belcher Brook Webster Brook Sawmill Brook	

Source: 2004 List of Connecticut Waterbodies Not Meeting Water Quality Standards (draft 5/14/02). The impaired waters list is updated by DEP every two to three years.

Figure 2-2 Impacts of Urbanization on the Hydrologic Cycle



Source: Federal Interagency SRWG, 2000.

United States. It is important to note that these tabulated values reflect impervious coverage within individual land uses, but do not reflect overall watershed imperviousness, for which the ecological stress thresholds apply. However, in developed watersheds with significant residential, commercial, and industrial development, overall watershed imperviousness often exceeds the ecological stress thresholds.

Table 2-2
Typical Impervious Coverage of Land Uses in the Northeast U.S.

Land Use	% Impervious Cover
Commercial and Business District	85-100
Industrial	70-80
High Density Residential	45-60
Medium Density Residential	35-45
Low Density Residential	20-40
Open Areas	0-10

Source: MADEP, 1997; Kauffman and Brant, 2000; Arnold and Gibbons, 1996; Soil Conservation Service, 1975.

The impacts of development on stream ecology can be grouped into four categories:

1. Hydrologic Impacts
2. Stream Channel and Floodplain Impacts
3. Water Quality Impacts
4. Habitat and Ecological Impacts

The extent of these impacts is a function of climate, level of imperviousness, and change in land use in a watershed (WEF and ASCE, 1998). Each of these impacts is described further in the following sections.

2.2 Hydrologic Impacts

Development can dramatically alter the hydrologic regime of a site or watershed as a result of increases in impervious surfaces. The impacts of development on hydrology may include:

- *Increased runoff volume*
- *Increased peak discharges*
- *Decreased runoff travel time*
- *Reduced groundwater recharge*
- *Reduced stream baseflow*
- *Increased frequency of bankfull and overbank floods*
- *Increased flow velocity during storms*
- *Increased frequency and duration of high stream flow*

Figure 2-4 depicts typical pre-development and post-development streamflow hydrographs for a developed watershed.

2.3 Stream Channel and Floodplain Impacts

Stream channels in urban areas respond to and adjust to the altered hydrologic regime that accompanies urbanization. The severity and extent of stream adjustment is a function of the degree of watershed imperviousness (WEF and ASCE, 1998). The impacts of development on stream channels and floodplains may include:

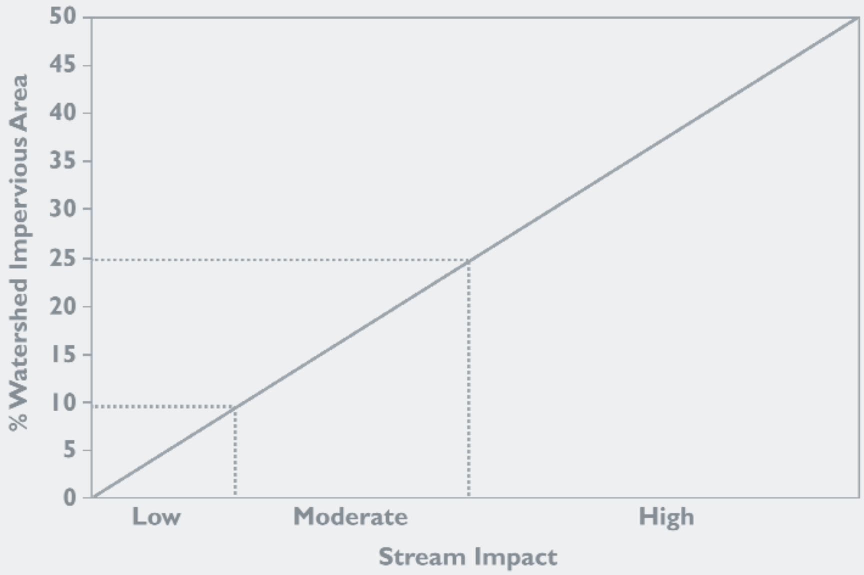
- *Channel scour, widening, and downcutting*
- *Streambank erosion and increased sediment loads*
- *Shifting bars of coarse sediment*
- *Burying of stream substrate*
- *Loss of pool/riffle structure and sequence*
- *Man-made stream enclosure or channelization*
- *Floodplain expansion*

2.4 Water Quality Impacts

Urbanization increases the discharge of pollutants in stormwater runoff. Development introduces new sources of stormwater pollutants and provides impervious surfaces that accumulate pollutants between storms. Structural stormwater collection and conveyance systems allow stormwater pollutants to quickly wash off during storm or snowmelt events and discharge to downstream receiving waters. By contrast, in undeveloped areas, natural processes such as infiltration, interception, depression storage, filtration by vegetation, and evaporation can reduce the quantity of stormwater runoff and remove pollutants. Impervious areas decrease the natural stormwater purification functions of watersheds and increase the potential for water quality impacts in receiving waters.

Urban land uses and activities can also degrade groundwater quality if stormwater with high pollutant loads is directed into the soil without adequate treatment. Certain land uses and activities, sometimes referred to as stormwater "hotspots" (e.g., commercial parking lots, vehicle service and maintenance facilities,

Figure 2-3
Relationship Between Watershed Imperviousness and Stream Health



Source: Adapted from Schueler, 1992 and Prince George's County, Maryland, 1999.

and industrial rooftops), are known to produce higher loads of pollutants such as metals and toxic chemicals. Soluble pollutants can migrate into groundwater and potentially contaminate wells in groundwater supply aquifer areas.

Table 2-3 lists the principal pollutants found in urban stormwater runoff, typical pollutant sources, related impacts to receiving waters, and factors that promote pollutant removal. **Table 2-3** also identifies those pollutants that commonly occur in a dissolved or soluble form, which has important implications for the selection and design of stormwater management practices described later in this manual. Chapter Three contains additional information on pollutant removal mechanisms for various stormwater pollutants.

Excess Nutrients

Urban stormwater runoff typically contains elevated concentrations of nitrogen and phosphorus that are most commonly derived from lawn fertilizer, detergents, animal waste, atmospheric deposition, organic matter, and improperly installed or failing septic systems. Nutrient concentrations in urban runoff are similar to those found in secondary wastewater effluents (American Public Works Association and Texas Natural Resource Conservation Commission). Elevated nutrient concentrations in stormwater runoff can result in excessive growth of vegetation or algae in streams, lakes, reservoirs, and estuaries, a process known as accelerated eutrophication. Phosphorus is typically the growth-limiting nutrient in freshwater systems, while nitrogen is growth-limiting in estuarine and marine systems. This means that in marine waters algal growth usually responds to the level of nitrogen in the water, and in fresh waters algal growth is usually stimulated by the level of available or soluble phosphorus (DEP, 1995).

Nutrients are a major source of degradation in many of Connecticut's water bodies. Excessive nitrogen loadings have led to hypoxia, a condition of low dissolved oxygen, in Long Island Sound. A Total Maximum Daily Load (TMDL) for nitrogen has been developed for Long Island Sound, which will restrict nitrogen loadings from point and non-point sources throughout Connecticut. Phosphorus in runoff has impacted the quality of many of Connecticut's lakes and ponds, which are susceptible to eutrophication from phosphorus loadings. Nutrients are also detrimental to submerged aquatic vegetation (SAV). Nutrient enrichment can favor the growth of epiphytes (small plants that grow attached to other things, such as blades of eelgrass) and increase amounts of phytoplankton and zooplankton in the water column, thereby decreasing available light. Excess nutrients can also favor the growth of macroalgae, which can dominate and displace eelgrass beds and dramatically change the food web (Deegan et al., 2002).

Table 2-3 Summary of Urban Stormwater Pollutants

Stormwater Pollutant	Potential Sources	Receiving Water Impacts	Removal Promoted by[1]
Stormwater Pollutant Excess Nutrients Nitrogen, Phosphorus (soluble)	Animal waste, fertilizers, failing septic systems, landfills, atmospheric deposition, erosion and sedimentation, illicit sanitary connections	Algal growth, nuisance plants, ammonia toxicity, reduced clarity, oxygen deficit (hypoxia), pollutant recycling from sediments, decrease in submerged aquatic vegetation (SAV)	Phosphorus: High soil exchangeable aluminum and/or iron content, vegetation and aquatic plants Nitrogen: Alternating aerobic and anaerobic conditions, low levels of toxicants, near neutral pH (7)
Sediments Suspended, Dissolved, Deposited, Sorbed Pollutants	Construction sites, streambank erosion, washoff from impervious surfaces	Increased turbidity, lower dissolved oxygen, deposition of sediments, aquatic habitat alteration, sediment and benthic toxicity	Low turbulence, increased residence time
Pathogens Bacteria, Viruses	Animal waste, failing septic systems, illicit sanitary connections	Human health risk via drinking water supplies, contaminated swimming beaches, and contaminated shellfish consumption	High light (ultraviolet radiation), increased residence time, media/soil filtration, disinfection
Organic Materials Biochemical Oxygen Demand, Chemical Oxygen Demand	Leaves, grass clippings, brush, failing septic systems	Lower dissolved oxygen, odors, fish kills, algal growth, reduced clarity	Aerobic conditions, high light, high soil organic content, low levels of toxicants, near neutral pH (7)
Hydrocarbons Oil and Grease	Industrial processes; commercial processes; automobile wear, emissions, and fluid leaks; improper oil disposal	Toxicity of water column and sediments, bioaccumulation in food chain organisms	Low turbulence, increased residence time, physical separation or capture techniques
Metals Copper, Lead, Zinc, Mercury, Chromium, Aluminum (soluble)	Industrial processes, normal wear of automobile brake linings and tires, automobile emissions and fluid leaks, metal roofs	Toxicity of water column and sediments, bioaccumulation in food chain organisms	High soil organic content, high soil cation exchange capacity, near neutral pH (7)
Synthetic Organic Chemicals Pesticides, VOCs, SVOCs, PCBs, PAHs (soluble)	Residential, commercial, and industrial application of herbicides, insecticides, fungicides, rodenticides; industrial processes; commercial processes	Toxicity of water column and sediments, bioaccumulation in food chain organisms	Aerobic conditions, high light, high soil organic content, low levels of toxicants, near neutral pH (7), high temperature and air movement for volatilization of VOCs
Deicing Constituents Sodium, Calcium, Potassium Chloride Ethylene Glycol Other Pollutants (soluble)	Road salting and uncovered salt storage. Snowmelt runoff from snow piles in parking lots and roads during the spring snowmelt season or during winter rain on snow events.	Toxicity of water column and sediments, contamination of drinking water, harmful to salt intolerant plants. Concentrated loadings of other pollutants as a result of snowmelt.	Aerobic conditions, high light, high soil organic content, low levels of toxicants, near neutral pH (7)
Trash and Debris	Litter washed through storm drain network	Degradation of aesthetics, threat to wildlife, potential clogging of storm drainage system	Low turbulence, physical straining/capture
Freshwater Impacts	Stormwater discharges to tidal wetlands and estuarine environments	Dilution of the high marsh salinity and encouragement of the invasion of brackish or upland wetland species such as Phragmites	Stormwater retention and volume reduction
Thermal Impacts	Runoff with elevated temperatures from contact with impervious surfaces (asphalt)	Adverse impacts to aquatic organisms that require cold and cool water conditions	Use of wetland plants and trees for shading, increased pool depths

Source: Adapted from DEP, 1995; Metropolitan Council, 2001; Watershed Management Institute, Inc., 1997.

1 Factors that promote removal of most stormwater pollutants include:
- Increasing hydraulic residence time
- Low turbulence
- Fine, dense, herbaceous plants
- Medium-fine textured soil

Sediments

Sediment loading to water bodies occurs from washoff of particles that are deposited on impervious surfaces such as roads and parking lots, soil erosion associated with construction activities, and streambank erosion. Although some erosion and sedimentation is natural, excessive sediment loads can be detrimental to aquatic life including phytoplankton, algae, benthic invertebrates, and fish, by interfering with photosynthesis, respiration, growth, and reproduction. Solids can either remain in suspension or settle to the bottom of the water body. Suspended solids can make the water cloudy or turbid, detract from the aesthetic and recreational value of a water body, and harm SAV, finfish, and shellfish. Sediment transported in stormwater runoff can be deposited in a stream or other water body or wetland and can adversely impact fish and wildlife habitat by smothering bottom dwelling aquatic life and changing the bottom substrate. Sediment deposition in water bodies can result in the loss of deep-water habitat and can affect navigation, often necessitating dredging. Sediment transported in stormwater runoff can also carry other pollutants such as nutrients, metals, pathogens, and hydrocarbons.

Pathogens

Pathogens are bacteria, protozoa, and viruses that can cause disease in humans. The presence of bacteria such as fecal coliform or enterococci is used as an indicator of pathogens and of potential risk to human health (DEP, 1995). Pathogen concentrations in urban runoff routinely exceed public health standards for water contact recreation and shellfishing. Sources of pathogens in stormwater runoff include animal waste from pets, wildlife, and waterfowl; combined sewers; failing septic systems; and illegal sanitary sewer cross-connections. High levels of indicator bacteria in stormwater have commonly led to the closure of beaches and shellfishing beds along coastal areas of Connecticut.

Organic Materials

Oxygen-demanding organic substances such as grass clippings, leaves, animal waste, and street litter are commonly found in stormwater. The decomposition of such substances in water bodies can deplete oxygen from the water, thereby causing similar effects to those caused by nutrient loading. Organic matter is of primary concern in water bodies where oxygen is not easily replenished, such as slower moving streams, lakes, and estuaries. An additional concern for unfiltered water supplies is the formation of trihalomethane (THM), a carcinogenic disinfection byproduct generated by the mixing of chlorine with water high in organic carbon (NYDEC, 2001).

Hydrocarbons

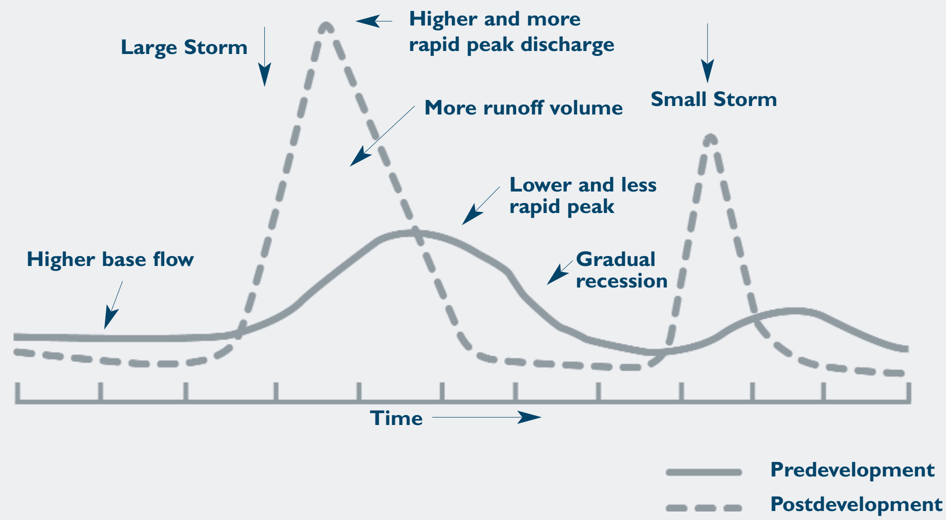
Urban stormwater runoff contains a wide array of hydrocarbon compounds, some of which are toxic to aquatic organisms at low concentrations (Woodward-Clyde, 1990). The primary sources of hydrocarbons in urban runoff are automotive. Source areas with higher concentrations of hydrocarbons in stormwater runoff include roads, parking lots, gas stations, vehicle service stations, residential parking areas, and bulk petroleum storage facilities.

Metals

Metals such as copper, lead, zinc, mercury, and cadmium are commonly found in urban stormwater runoff. Chromium and nickel are also frequently present (USEPA, 1983). The primary sources of these metals in stormwater runoff are vehicular exhaust residue, fossil fuel combustion, corrosion of galvanized and chrome-plated products, roof runoff, stormwater runoff from industrial sites, and the application of deicing agents. Architectural copper associated with building roofs, flashing, gutters, and downspouts has been shown to be a source of copper in stormwater runoff in Connecticut and other areas of the country (Barron, 2000; Tobiason, 2001). Marinas have also been identified as a source of copper and aquatic toxicity to inland and marine waters (Sailer Environmental, Inc. 2000). Washing or sand-blasting of boat hulls to remove salt and barnacles also removes some of the bottom paint, which contains copper and zinc additives to protect hulls from deterioration.

In Connecticut, discharge of metals to surface waters is of particular concern. Metals can be toxic to aquatic organisms, can bioaccumulate, and have the potential to contaminate drinking water supplies. Many major rivers in Connecticut have copper levels that exceed Connecticut's Copper Water Quality Criteria. Although metals generally attach themselves to the solids in stormwater runoff or receiving waters, recent studies have demonstrated that dissolved metals, particularly copper and zinc, are the primary toxicants in stormwater runoff from industrial facilities throughout Connecticut (Mas et al., 2001; New England Bioassay, Inc., 2001). Additionally, stormwater runoff can contribute to elevated metals in aquatic sediments. The metals can become bioavailable where the bottom sediment is anaerobic (without oxygen) such as in a lake or estuary. Metal accumulation in sediments has resulted in impaired aquatic habitat and more difficult maintenance dredging operations in estuaries because of the special handling requirements for contaminated sediments.

Figure 2-4 Changes in Stream Hydrology as a Result of Urbanization



Source: Schueler, 1992, in Metropolitan Council, 2001.

Synthetic Organic Chemicals

Synthetic organic chemicals can also be present at low concentrations in urban stormwater. Pesticides, phenols, polychlorinated biphenyls (PCBs), and polynuclear or polycyclic aromatic hydrocarbons (PAHs) are the compounds most frequently found in stormwater runoff. Such chemicals can exert varying degrees of toxicity on aquatic organisms and can bioaccumulate in fish and shellfish. Toxic organic pollutants are most commonly found in stormwater runoff from industrial areas. Pesticides are commonly found in runoff from urban lawns and rights-of-way (NYDEC, 2001). A review of monitoring data on stormwater runoff quality from industrial facilities has shown that PAHs are the most common organic toxicants found in roof runoff, parking area runoff, and vehicle service area runoff (Pitt et al., 1995).

Deicing Constituents

Salting of roads, parking lots, driveways, and sidewalks during winter months and snowmelt during the early spring result in the discharge of sodium, chloride, and other deicing compounds to surface waters via stormwater runoff. Excessive amounts of sodium and chloride may have harmful effects on water, soil and vegetation, and can also accelerate corrosion of metal surfaces. Drinking water supplies, particularly groundwater wells, may be contaminated by runoff from roadways where deicing compounds have been applied or from highway facilities where salt mixes are improperly stored. In addition, sufficient concentrations of chlorides may prove toxic to certain aquatic species. Excess sodium in drinking water can lead to health problems in infants ("blue baby syndrome") and individuals on low sodium diets. Other deicing compounds may contain nitrogen, phosphorus, and oxygen demanding substances. Antifreeze from automobiles is a source of phosphates, chromium, copper, nickel, and cadmium.

Other pollutants such as sediment, nutrients, and hydrocarbons are released from the snowpack during the spring snowmelt season and during winter rain-on-snow events. The pollutant loading during snowmelt can be significant and can vary considerably during the course of the melt event (NYDEC, 2001). For example, a majority of the hydrocarbon load from snowmelt occurs during the last 10 percent of the event and towards the end of the snowmelt season (Oberts, 1994). Similarly, PAHs, which are hydrophobic materials, remain in the snowpack until the end of the snowmelt season, resulting in highly concentrated loadings (Metropolitan Council, 2001).

Trash and Debris

Trash and debris are washed off of the land surface by stormwater runoff and can accumulate in storm drainage systems and receiving waters. Litter detracts from the aesthetic value of water bodies and can harm aquatic life either directly (by being mistaken for food) or indirectly (by habitat modification). Sources of trash and debris in urban stormwater runoff include residential yard waste, commercial parking lots, street refuse, combined sewers, illegal dumping, and industrial refuse.

Freshwater Impacts

Discharge of freshwater, including stormwater, into brackish and tidal wetlands can alter the salinity and hydroperiod of these environments, which can encourage the invasion of brackish or freshwater wetland species such as Phragmites.

Thermal Impacts

Impervious surfaces may increase temperatures of stormwater runoff and receiving waters. Roads and other impervious surfaces heated by sunlight may transport thermal energy to a stream during storm events. Direct exposure of sunlight to shallow ponds and impoundments as well as unshaded streams may further elevate water temperatures. Elevated water temperatures can exceed fish and invertebrate tolerance limits, reducing survival and lowering resistance to disease. Coldwater fish such as trout may be eliminated, or the habitat may become marginally supportive of coldwater species. Elevated water temperatures also contribute to decreased oxygen levels in water bodies and dissolution of solutes.

Concentrations of pollutants in stormwater runoff vary considerably between sites and storm events. Typical average pollutant concentrations in urban stormwater runoff in the Northeast United States are summarized in **Table 2-4.**

Table 2-4
Average Pollutant Concentrations in Urban Stormwater Runoff

Constituent	Units	Concentration
Total Suspended Solids[1]	mg/l	54.5
Total Phosphorus[1]	mg/l	0.26
Soluble Phosphorus[1]	mg/l	0.10
Total Nitrogen[1]	mg/l	2.00
Total Kjeldahl Nitrogen[1]	mg/l	1.47
Nitrite and Nitrate[1]	mg/l	0.53
Copper[1]	μg/l	11.1
Lead[1]	μg/l	50.7
Zinc[1]	μg/l	129
BOD[1]	mg/l	11.5
COD[1]	mg/l	44.7
Organic Carbon[2]	mg/l	11.9
PAH[3]	mg/l	3.5
Oil and Grease[4]	mg/l	3.0
Fecal Coliform[5]	Colonies/100 ml	15,000
Fecal Strep[5]	Colonies/100 ml	35,400
Chloride (snowmelt)[6]	mg/l	116

Source: Adapted from NYDEC, 2001; original sources are listed below.
[1]Pooled Nationwide Urban Runoff Program/USGS (Smullen and Cave, 1998)
[2]Derived from National Pollutant Removal Database (Winer, 2000)
[3]Rabanal and Grizzard, 1996
[4]Crunkilton et al., 1996
[5]Schueler, 1999
[6]Oberts, 1994
mg/l = milligrams per liter
μg/l= micrograms per liter

2.5 Habitat and Ecological Impacts

Changes in hydrology, stream morphology, and water quality that accompany the development process can also impact stream habitat and ecology. A large body of research has demonstrated the relationship between urbanization and impacts to aquatic habitat and organisms (**Table 2-5**). Habitat and ecological impacts may include:

- *A shift from external (leaf matter) to internal (algal organic matter) stream production*
- *Reduction in the diversity, richness, and abundance of the stream community (aquatic insects, fish, amphibians)*
- *Destruction of freshwater wetlands, riparian buffers, and springs*
- *Creation of barriers to fish migration*

2.6 Impacts on Other Receiving Environments

The majority of research on the ecological impacts of urbanization has focused on streams. However, urban stormwater runoff has also been shown to adversely impact other receiving environments such as wetlands, lakes, and estuaries. Development alters the physical, geochemical, and biological characteristics of wetland systems. Lakes, ponds, wetlands, and SAV are impacted through deposition of sediment and particulate pollutant loads, as well as accelerated eutrophication caused by increases in nutrient loadings. Estuaries experience increased sedimentation and pollutant loads, and more extreme salinity swings caused by increased runoff and reduced baseflow. **Table 2-5** summarizes the effects of urbanization on these receiving environments.

Table 2-5 Effects of Urbanization on Other Receiving Environments

Receiving Environment	Impacts
Wetlands	❍ Changes in hydrology and hydrogeology ❍ Increased nutrient and other contaminant loads ❍ Compaction and destruction of wetland soil ❍ Changes in wetland vegetation ❍ Changes in or loss of habitat ❍ Changes in the community (diversity, richness, and abundance) of organisms ❍ Loss of particular biota ❍ Permanent loss of wetlands
Lakes and Ponds	❍ Impacts to biota on the lake bottom due to sedimentation ❍ Contamination of lake sediments ❍ Water column turbidity ❍ Aesthetic impairment due to floatables and trash ❍ Increased algal blooms and depleted oxygen levels due to nutrient enrichment, resulting in an aquatic environment with decreased diversity ❍ Contaminated drinking water supplies
Estuaries	❍ Sedimentation in estuarial streams and SAV beds ❍ Altered hydroperiod of brackish and tidal wetlands, which results from larger, more frequent pulses of fresh water and longer exposure to saline waters because of reduced baseflow ❍ Hypoxia ❍ Turbidity ❍ Bio-accumulation ❍ Loss of SAV due to nutrient enrichment ❍ Scour of tidal wetlands and SAV ❍ Short-term salinity swings in small estuaries caused by the increased volume of runoff which can impact key reproduction areas for aquatic organisms

Source: Adapted from WEF and ASCE, 1998.

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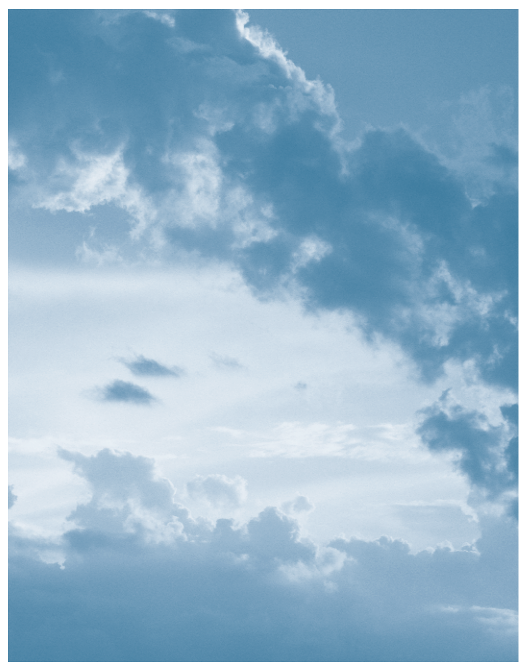
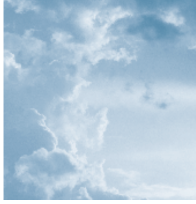
Chapter 3
Preventing and Mitigating Stormwater Impacts





Volume 1: Background

Chapter 3

Preventing and Mitigating Stormwater Impacts

3.1 Introduction

Stormwater management involves the selective use of various management measures to cost-effectively address the adverse water quality and quantity impacts of urban stormwater runoff described in Chapter Two. **Table 3-1** lists the major elements and associated objectives of a comprehensive stormwater management strategy.

Effective site planning and design is the most critical and potentially beneficial element of a successful stormwater management program since it addresses the root causes of both stormwater quality and quantity problems early in the development process. Source controls and pollution prevention, as well as construction erosion and sedimentation controls, are also key elements for preventing or mitigating stormwater quality problems. These preventive measures can reduce the size and scope of stormwater treatment and flood control facilities. However, it is also recognized that stormwater treatment and flood control measures are often effective and necessary to achieve water quality and quantity control objectives. **Figure 3-1** shows the relationship and recommended hierarchy of these stormwater management elements.

Table 3-1 Elements of a Comprehensive Stormwater Management Strategy

Element	Addresses Water Quality or Quantity?
Effective site planning and design	Quality and quantity
Source control practices and pollution prevention	Quality
Construction erosion and sedimentation controls	Quality
Stormwater treatment practices	Quality (primary), quantity (secondary)
Drainage design and flood control	Quantity (primary), quality (secondary)

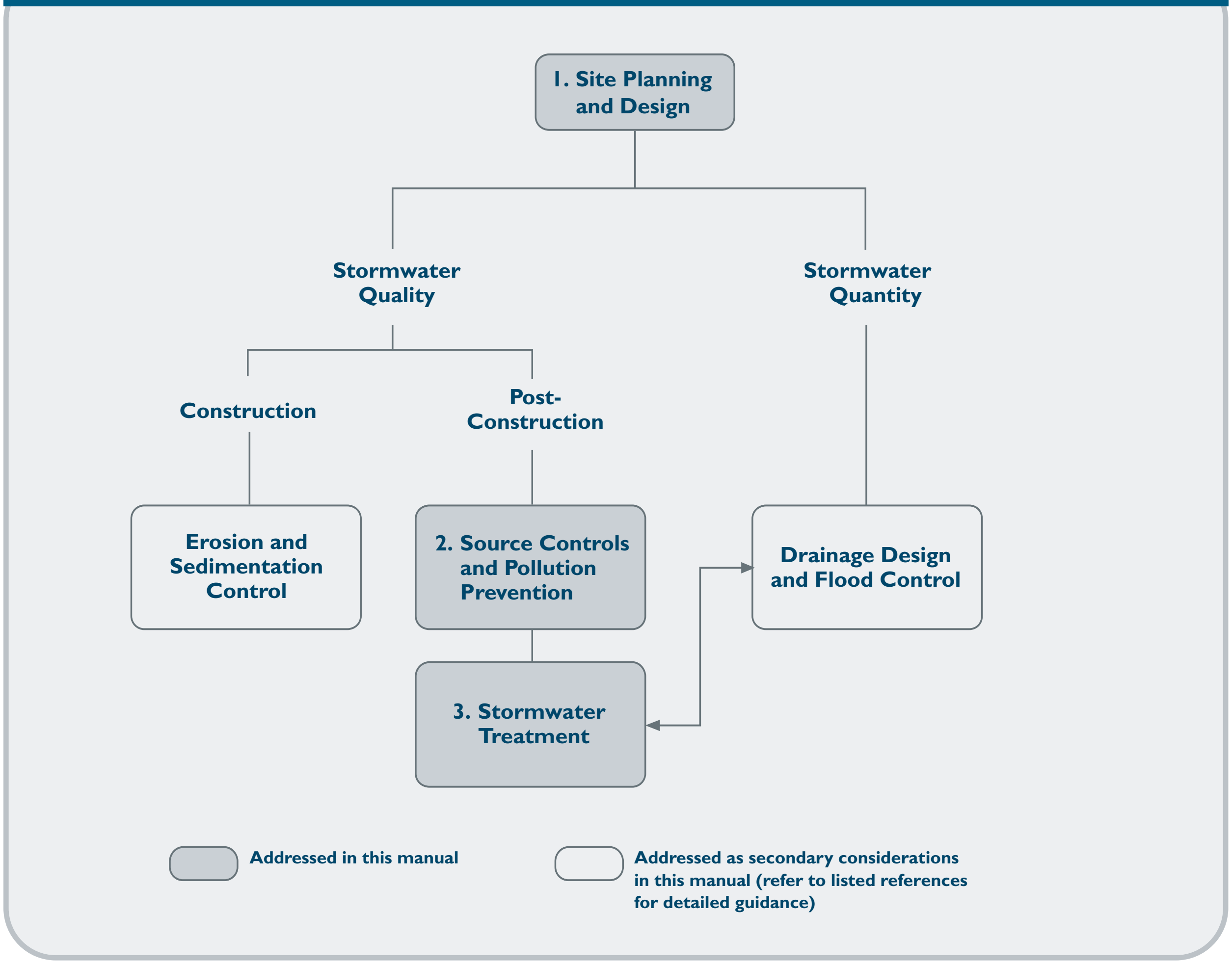
This manual primarily addresses water quality controls through site planning and design, source controls and pollution prevention, and stormwater treatment practices, which are highlighted in **Figure 3-1.** Construction erosion and sediment control, and stormwater quantity control (i.e., flood control and drainage design), are addressed as secondary topics as they relate to water quality. For instance, source controls and stormwater treatment practices can also provide peak runoff attenuation and flood control benefits. Other guidance documents, as well as local ordinances and requirements, are recommended sources of information on these topics, as discussed later in this chapter.

3.2 Guiding Stormwater Management Principles

A comprehensive stormwater management strategy should prevent or mitigate urban runoff problems and protect beneficial uses of receiving waters in a cost-effective manner. The stormwater management measures described in this manual are designed to accomplish this objective by adhering to the following guiding principles:

- *Preserve pre-development site hydrology (i.e., runoff, infiltration, interception, evapotranspiration, groundwater recharge, and stream baseflow) to the extent possible*
- *After construction has been completed and the site is permanently stabilized, reduce the average annual total suspended solids loadings by 80 percent. For high quality receiving waters and sites with the highest potential for significant pollutant loadings, reduce post-development pollutant loadings so that average annual post-development loadings do not exceed pre-development loadings (i.e., no net increase)*

Figure 3-1 Relationship of Stormwater Management Elements



- *Preserve and protect wetlands, stream buffers, natural drainage systems and other natural features that provide water quality and quantity benefits*
- *Manage runoff velocity and volume in a manner that maintains or improves the physical and biological character of existing drainage systems and prevents increases in downstream flooding/streambank erosion*
- *Prevent pollutants from entering receiving waters and wetlands in amounts that exceed the systems' natural ability to assimilate the pollutants and provide the desired functions*
- *Seek multi-objective benefits (i.e., flood control, water quality, recreation, aesthetics, habitat) from stormwater control measures*

3.3 Site Planning and Design

Effective site planning and design (Chapter Four) consists of preventive measures that address the root causes of stormwater problems by maintaining predevelopment hydrologic functions and pollutant removal mechanisms to the extent practical. Site planning that integrates comprehensive stormwater management from the outset is the most effective way to address the adverse water quality and quantity impacts of stormwater runoff from new development and redevelopment projects. Often these site design techniques can reduce or eliminate the need for costly peak flow attenuation and stormwater treatment. This manual emphasizes the use of effective site planning and design techniques early on in the site development process to achieve the greatest stormwater quantity and quality benefits. Site planning and design practices described in this manual include:

- *Alternative site design for streets and parking lots and lot development*

- *Low Impact Development (LID) management practices*
- *Watershed planning*

3.4 Source Control Practices and Pollution Prevention

Source control practices and pollution prevention (Chapter Five) are operational practices that can reduce the types and concentrations of pollutants in stormwater runoff by limiting the generation of pollutants at their source. The guiding principle behind these techniques is to minimize contact of stormwater with potential pollutants, thereby reducing pollutant loads and the size and cost of stormwater treatment. This manual emphasizes the use of source control practices and pollution prevention, in conjunction with effective site planning and design, to reduce the need for and scope of stormwater treatment. Source control practices commonly implemented at residential, commercial, and industrial sites are discussed in this manual, including:

- *Street and Parking Lot Sweeping*
- *Roadway Deicing/Salt Storage*
- *Storm Drainage System Maintenance*
- *Other Road, Highway, and Bridge Maintenance*
- *Illicit Discharge Detection and Elimination*
- *Commercial and Industrial Pollution Prevention Plans*
- *Animal Waste Management*
- *Lawn Care and Landscaping Practices*
- *Model Stormwater Ordinances*
- *Public Education*

3.5 Construction Erosion and Sedimentation Control

As described in Chapter One, soil erosion and sedimentation control is addressed by the Soil Erosion and Sediment Control Act (CGS §§22a-325 through 22a-335, inclusive). The primary goal of the Act is to reduce soil erosion from stormwater runoff and nonpoint sediment pollution from land being developed. Controlling soil erosion and sedimentation during construction is addressed through a combination of measures that are described in a site-specific Erosion and Sediment Control (E&SC) Plan. The basic principles of effective soil erosion and sediment control include:

- *Use effective site planning to avoid sensitive areas such as wetlands and watercourses*
- *Keep land disturbance to a minimum*
- *Stabilize disturbed areas*
- *Phase land disturbance on larger projects, starting subsequent phases after disturbed areas are stabilized*
- *Keep runoff velocities low*
- *Protect disturbed areas from stormwater runoff*
- *Properly install perimeter control practices*
- *Limit construction during months when runoff rates are higher due to decreased infiltration or extreme rainfall events*
- *Implement a thorough maintenance and follow-up program*
- *Assign responsibility for the maintenance program*

As shown in **Figure 3-1,** soil erosion and sediment control is a key component of any stormwater management strategy in order to reduce the impacts of stormwater runoff during construction activities. Although many of the vegetative, filtration, and infiltration stormwater management practices contained in this manual are based on the above principles, this manual does not address construction soil erosion and sediment control practices. Municipal ordinances contain specific soil erosion and sediment control requirements for developments disturbing more than one-half acre. Additionally, the 2002 revision of the *Connecticut Guidelines for Soil Erosion and Sediment Control, DEP Bulletin 34* (Connecticut Council on Soil and Water Conservation and the Connecticut Department of Environmental Protection, 2002) contains detailed technical guidance on specific erosion and sediment control practices and recommended procedures for developing an effective E&SC Plan. Copies of this guidance manual have been issued to each local Planning, Zoning, and Inland Wetlands and Watercourses Office.

3.6 Stormwater Treatment Practices

Stormwater treatment practices, which are the focus of the second half of this Manual, are primarily designed to remove pollutants from stormwater runoff. In addition to water quality treatment, these practices can also provide groundwater recharge, stream channel protection, and peak runoff attenuation. As described above, stormwater treatment practices should be selected and designed only after consideration of effective site planning/design and

Table 3-2 Stormwater Pollutant Removal Mechanisms

Mechanism	Pollutants Affected
Gravity settling of particulate pollutants	Solids, BOD, pathogens, particulate COD, phosphorus, nitrogen, synthetic organics, particulate metals
Filtration and physical straining of pollutants through a filter media or vegetation	Solids, BOD, pathogens, particulate COD, phosphorus, nitrogen, synthetic organics, particulate metals
Infiltration of particulate and dissolved pollutants	Solids, BOD, pathogens, particulate COD, phosphorus, nitrogen, synthetic organics, particulate metals
Adsorption on particulates and sediments	Dissolved phosphorus, metals, synthetic organics
Photodegradation	COD, petroleum hydrocarbons, synthetic organics, pathogens
Gas exchange and volatilization	Volatile organics, synthetic organics
Biological uptake and biodegradation	BOD, COD, petroleum hydrocarbons, synthetic organics, phosphorus, nitrogen, metals
Chemical precipitation	Dissolved phosphorus, metals
Ion exchange	Dissolved metals
Oxidation	COD, petroleum hydrocarbons, synthetic organics
Nitrification and denitrification	Ammonia, nitrate, nitrite
Density separation and removal of floatables	Petroleum hydrocarbons

source controls, which can reduce the volume of runoff and the size and cost of stormwater treatment.

Stormwater treatment practices are designed for small storms to achieve water quality objectives (i.e., smaller than a one-year return frequency storm), in contrast to drainage and flood control facilities, which are typically designed for the two-year and larger storms. However, many stormwater treatment practices can also be designed for flood control purposes and vice versa. Stormwater treatment practices can be integrated into the landscape, drainage or flood control system, and other spaces of development projects. When properly located, designed, and maintained, stormwater treatment practices can be amenities for, rather than detractions from, development projects.

Pollutant Removal Mechanisms

Stormwater treatment practices remove pollutants from stormwater through various physical, chemical, and biological mechanisms. **Table 3-2** lists the major stormwater pollutant removal mechanisms and the affected stormwater pollutants.

Since many pollutants in urban stormwater runoff are attached to solid particles, treatment practices designed to remove suspended solids from runoff will remove other pollutants as well. Exceptions to this rule include nutrients, which are often in a dissolved form, soluble metals and organics, and extremely fine particulates (i.e., diameter smaller than 10 microns), which can only be removed by treatment practices other than traditional separation methods.

Primary and Secondary Stormwater Treatment Practices

Stormwater treatment practices described in this Manual include both primary treatment practices, which provide demonstrated, acceptable levels of water quality treatment, and secondary treatment practices which are not suitable as stand-alone treatment facilities but can be used for pretreatment or as supplemental practices. This Manual includes five major categories of primary stormwater treatment practices:

- *Stormwater ponds*
- *Stormwater wetlands*
- *Infiltration practices*
- *Filtering practices*
- *Water quality swales*

Examples of secondary stormwater treatment practices described in the Manual include traditional practices such as dry detention ponds, vegetated filter strips and level spreaders, oil/particle separators, and deep sump catch basins. The Manual also includes innovative and emerging technologies as secondary treatment practices. These technologies are designed to remove a variety of stormwater pollutants, but have not been evaluated in sufficient detail to demonstrate the capability to meet established performance standards. Sizing and selection criteria for stormwater treatment practices are addressed in Chapter Seven and Chapter Eight, respectively.

New Development Versus Retrofits

Stormwater treatment practices can be implemented for new development projects as well as existing, developed sites. Retrofitting existing developments can improve water quality mitigation functions of older, poorly designed, or poorly maintained stormwater management systems. Incorporating stormwater retrofits into developed sites is typically more difficult than implementing treatment practices for new development due to the numerous site constraints associated with developed areas such as subsurface utilities, buildings, conflicting land uses, and maintenance access. Chapter Ten describes common stormwater retrofit options for existing development and redevelopment projects, including:

- *Stormwater collection system retrofits*
- *Stormwater management facility retrofits*
- *New stormwater controls at storm drain outfalls*
- *In-stream practices in existing drainage channels*
- *Parking lot stormwater retrofits*
- *Wetland creation and restoration*

3.7 Stormwater Quantity Control

Stormwater quantity controls include drainage and flood control. As shown in **Figure 3-1,** stormwater quantity and quality controls are related and complementary elements of an effective stormwater management strategy. Stormwater drainage systems can be designed to reduce the potential erosive velocity of stormwater runoff and maintain pre-development hydrology through infiltration and the use of vegetated conveyances, thereby preserving the water quality mitigation functions of a site. Similarly, stormwater treatment practices such as stormwater ponds and wetlands can provide dual flood control and water quality treatment benefits.

This Manual addresses the topics of drainage design and flood control as they relate to stormwater quality management. The Manual identifies stormwater treatment practices that also provide peak runoff attenuation and channel protection functions. However, this document is not intended to serve as a drainage or flood control design manual. Other recommended guidance documents and manuals on these topics include:

- *2000 Connecticut Department of Transportation Drainage Manual, October 2000*
- *Connecticut Department of Environmental Protection, Model Hydraulic Analysis, revised February 13, 2002*
- *Urban Hydrology for Small Watersheds, TR-55, Natural Resource Conservation Service (formerly Soil Conservation Service), June 1986*

In addition, municipal ordinances, as well as some DEP regulatory programs, contain specific stormwater quantity control requirements for land development projects, as described in Chapter One.

Drainage Design and Flood Control Principles for Water Quality

The traditional approach to drainage design has been to collect and remove runoff from the site as quickly as possible through the use of curbs, gutters, catch basins, and storm sewers, often resulting in the discharge of polluted runoff directly to receiving waters. While this approach effectively removes runoff from a site, it does not address water quality or downstream flooding and erosion issues. Similarly, the traditional approach to flood control has been to attenuate peak runoff to pre-development levels through the use of detention and retention ponds. While stormwater detention or retention facilities can effectively reduce peak discharge rates, they also typically prolong the duration of elevated flows and do not reduce runoff volumes unless infiltration is incorporated into their design. Historically, these facilities have not adequately addressed problems associated with water quality, runoff volume, and downstream channel erosion.

Drainage and flood control facilities should be designed according to the following principles to address water quality objectives:

- *Identify and assess existing stormwater runoff rates and volumes at the site, as well as downstream flooding and erosion concerns.*
- *Preserve pre-development hydrologic conditions, including peak discharge, runoff volume, groundwater recharge, and natural drainage paths.*
- *Reduce the potential for increases in runoff quantity by minimizing impervious surfaces and maximizing infiltration of stormwater runoff. Eliminate curbs where possible and encourage sheet flow from paved areas. If*

curbing is required, use Cape Cod curbing or other similar curbing, which allows amphibians to climb.

- *Encourage infiltration of stormwater through the use of vegetated depressions, swales, rain gardens and bioretention, and other vegetated drainageways to convey and hold stormwater and provide for a slow recharge to groundwater, where soils permit. Special care must be taken in areas of sensitive groundwater resources such as aquifer protection areas and groundwater supply wells in order to prevent their contamination. In addition, in areas with soil or groundwater contamination, the potential for infiltrated stormwater to mobilize contaminants must also be considered.*
- *Control increases in stormwater runoff volume and peak flows through properly designed and located stormwater management facilities. Manage stormwater so that both the volume and peak rate of runoff from the site after development does not exceed the volume and peak rate of runoff from the site prior to development.*
- *Encourage the development of watershed-based stormwater management strategies to effectively control the cumulative effects of increases in runoff volume and peak flows at critical locations throughout the watershed. Coordinate the timing of detention basin outflows to avoid increases in peak flows in downstream watercourses.*
- *Use adequate outlet protection at drainage outfalls to reduce discharge velocities, disperse flow, and prevent or reduce downstream erosion.*
- *Coordinate construction erosion and sediment control measures with post-construction stormwater management measures. For example, a sediment basin designed to trap sediment during the construction phase of a project may sometimes be converted to a detention basin or stormwater treatment facility to meet peak runoff attenuation or water quality mitigation objectives following construction.*
- *Retain on-site the volume of runoff generated by the first inch of rainfall from areas adjacent to or within 500 feet of tidal salt marshes and estuarine waters. Excessive quantities of fresh water can be a pollutant to tidal wetlands and cause a decrease in vegetative diversity and wetland productivity.*
- *Protect wetland and watercourse resources from stormwater discharges. Do not drain stormwater directly to a wetland or watercourse or to a municipal storm drainage system that drains directly to a wetland or watercourse without adequate stormwater treatment. Protect wetlands, watercourses, and submerged aquatic vegetation from scour.*

3.8 Watershed Management

Stormwater management is most effectively undertaken in the context of a watershed management plan. A watershed management plan is a comprehensive framework for applying management tools in a manner that achieves the water resources goals for the watershed as a whole (CWP, 1998). Typically, watershed management plans are developed from watershed studies undertaken by one or more municipalities located within the watershed. The watershed approach has emerged over the past decade as the recommended approach for addressing nonpoint source pollution problems, including polluted stormwater runoff. Watershed planning offers the best means to:

- *Address cumulative impacts derived from a number of new land development projects*
- *Plan for mitigation to address cumulative impacts from existing developments*
- *Focus efforts and resources on identified priority water bodies and pollutant sources in a watershed*
- *Achieve noticeable improvements to impaired waters or waters threatened with impairment*

The watershed approach is built on three main principles. First, the target watersheds should be those where stormwater impacts pose the greatest risk to human health, ecological resources, desirable uses of the water, or a combination of these. Second, parties with a stake in the specific local situation (i.e., stakeholders) should participate in the analysis of problems and the creation of solutions. Third, the actions undertaken should draw on the full range of methods and tools available, integrating them into a coordinated, multi-organization attack on the problems. The watershed approach has the following significant advantages over traditional piecemeal approaches to stormwater management that require individual land developments to provide on-site stormwater management facilities (adapted from Aldrich, 1988):

Lower capital and O&M cost: Typically, watershed management plans yield fewer and larger stormwater management facilities. Economies of scale are achievable in capital costs and especially in O&M. Strategic placement of regional facilities permits concentrating funds on areas where potential benefits are greatest. Cost sharing arrangements significantly reduce the net cost of stormwater management to the community as a whole.

Increased effectiveness on a watershed-wide basis: Often different portions of watersheds require different types of stormwater controls. Watershed planning permits the siting of a variety of on-site and regional facilities in locations where the greatest benefits are achieved.

Greater use of nonstructural measures: Often the most practical stormwater controls involve nonstructural measures such as land acquisition, floodplain zoning, subdivision drainage ordinances, and land use controls. Watershed planning provides a coordinated, comprehensive framework and decision-making process to allow the effective implementation of these measures.

Less risk of negative "spillover" effects: The piecemeal approach may adequately solve localized drainage problems, but seldom addresses downstream impacts. Thus, dynamic interactions between upstream drainage improvements may actually increase downstream flooding. An objective of watershed planning is to account for these upstream interactions and achieve solutions to both localized and regional stormwater management concerns.

Watershed management plans should include recommended criteria for stormwater source controls and treatment practices in the watershed. These criteria are based on watershed-specific factors such as physical attributes, land use, pollution sources, and sensitive receptors, and are the basis for selecting and locating stormwater controls in the watershed. At a minimum, a watershed management plan should contain the elements listed in **Table 3-3** to address stormwater-related issues.

The watershed management plan should address integrating flood control and stormwater management controls with community needs, including open space, aesthetics, and other environmental objectives such as habitat or river restoration. This synchronization with other programs can create better funding opportunities and enhance the overall benefit of the stormwater management practices in the watershed.

On-Site Versus Regional Approaches

Watershed management plans can identify conditions and locations in the watershed where regional stormwater management facilities may be more appropriate or effective than on-site controls. On-site and regional stormwater management approaches are illustrated schematically in **Figure 3-2.** These approaches apply to both stormwater quality and quantity controls.

In the on-site approach, land developers have responsibility for deploying treatment practices and runoff controls at individual development sites. Developers are responsible for constructing on-site stormwater management facilities to control stormwater pollutant loadings and runoff from the site. The local government is responsible for reviewing the design of stormwater management facilities relative to specified design criteria, for inspecting the constructed facilities to ensure conformance with the design, and for ensuring that operation and maintenance plans are implemented for the facilities (Novotny, 1995).

The regional approach involves strategically siting stormwater management facilities to control stormwater runoff from multiple development projects or large drainage areas. Local or regional governments assume the capital costs for constructing the regional facilities. Capital costs are typically recovered from upstream developers as development occurs. Individual regional facilities are often sited and phased in as development occurs according to a comprehensive watershed management plan. Municipalities generally assume responsibility for operation and maintenance of regional stormwater facilities (Novotny, 1995).

Both approaches have a number of advantages and disadvantages, which are summarized in **Table 3-4.** Most of the advantages of the regional approach can be attributed to the need for fewer stormwater management facilities that are strategically located throughout the watershed (Novotny, 1995). However, the on-site approach addresses stormwater pollution close to its source, offers greater opportunities to preserve pre-development hydrologic conditions, and reduces the overall volume of stormwater runoff. Historically the on-site approach to stormwater management has been more common in Connecticut. The major drawbacks that have limited the widespread use of the regional approach include significant required advanced planning, financing, and land acquisition. Local governments must finance, design, and construct regional stormwater facilities before the majority of the watershed is developed, with reimbursement by developers over build-out periods of many years (WEF and ASCE, 1992). Due to these limitations, the regional approach generally is more appropriate for:

- *Highly developed watersheds with severe water quality and flooding impacts, where stormwater controls for new development alone cannot adequately address the impacts in these areas*
- *Watersheds where the timing of peak runoff may increase downstream flooding if on-site peak runoff attenuation criteria are applied uniformly throughout the watershed*

(Pennsylvania Association of Conservation Districts et al., 1998). In most watersheds, a mix of regional and on-site controls is desirable and has the greatest potential for success when implemented as part of a comprehensive watershed management plan. (DEP, 1995).

Table 3-3 Elements of a Watershed Management Plan

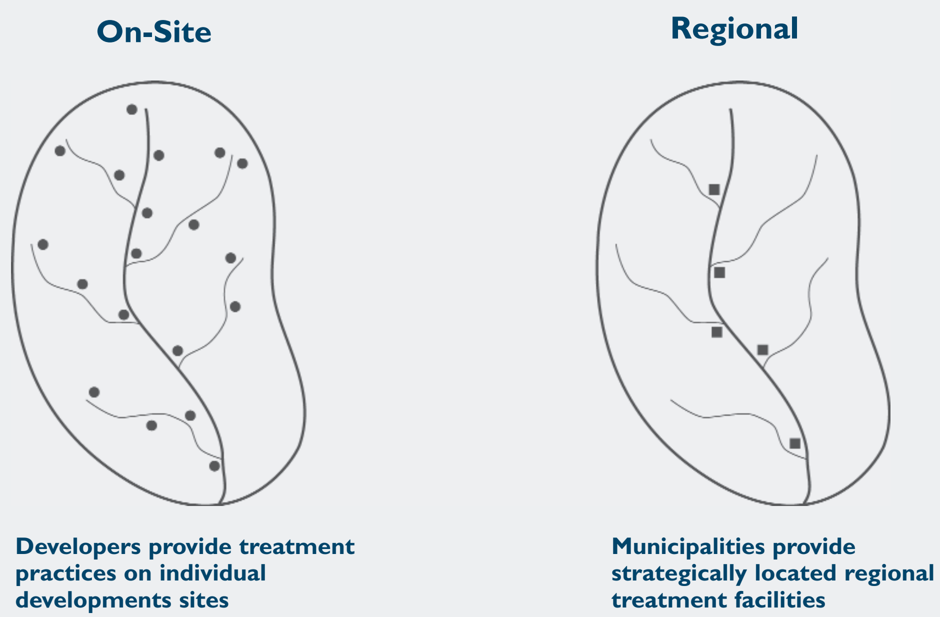
Plan Elements	
Watershed delineation and identification of watershed characteristics such as topography, soils, surficial geology, impervious cover, and land use (current and projected)	A runoff hydrograph analysis of the watershed for floods of an appropriate duration, including a 24 hour event, with average return frequencies of 2, 10, 25, and 100 years for existing and future land uses
Inventory of flood hazard areas as identified by Flood Insurance Studies or DEP, plus historic floods and damages	The relationship between the computed peak flow rates and gauging station data, with modification or calibration of the hydrographs to obtain a reasonable fit where necessary
An evaluation of watercourses, including areas of limited flow capacity, bank or bed erosion, sediment deposition, water quality, principle water uses and users, recreation areas, morphology classification, and channel stability	Identification of the peak rate of runoff at various key points in the watershed, and the relative timing of the peak flows
An inventory and evaluation of hydraulic structures, including culverts, bridges, dams and dikes with information on their flow capacity and physical condition	Identification of points in the watershed where hydraulic structures or watercourses are inadequate under existing or anticipated future conditions
An inventory of significant water storage areas, including principal impoundments, floodplains, and wetlands	Recommendations on how the subwatershed's runoff can be managed to minimize any harmful downstream (flooding) impacts
Identification of sensitive and impaired wetlands and waterbodies	Existing and projected future pollutant loads, impacts of these loads, and pollution reduction goals
Evaluation of functional value of wetlands to identify sensitive and high quality wetland resources	Existing and projected aquatic habitat disturbances and goals for habitat restoration
Sensitive groundwater recharge or aquifer protection areas	Recommendations for watershed-specific stormwater treatment controls, conceptual design, and operation and maintenance (O&M) needs and responsibilities
Identification of existing problem land uses and impacts on water quality	Water quality monitoring program
Land use restrictions in sensitive areas	Prioritized implementation plan for recommendations
Inventory of local wetlands, conservation, planning and zoning, and subdivision regulations of the watershed municipalities to identify potential regulatory changes for addressing stormwater impacts	Identification of public water supply watershed areas and DEP-delineated aquifer recharge areas.

Table 3-4
Comparison of On-Site and Regional Stormwater Management Approaches

Approach	Advantages	Disadvantages
On-Site	❍ Requires little or no advanced planning ❍ Addresses stormwater pollution close to its source, thereby reducing the volume of stormwater runoff and the need for treatment controls ❍ Provides greater groundwater recharge benefits	❍ Results in a large number of facilities that may not be adequately maintained by developers or home-owners ❍ Consumes on-site land that could be used for other purposes ❍ May increase downstream flooding and quantity control problems
Regional	❍ Reduced capital costs through economies of scale in designing and constructing regional facilities ❍ Reduced maintenance costs because there are fewer facilities to maintain ❍ Greater reliability because regional facilities are more likely to receive long-term maintenance ❍ Nonpoint pollutant loadings from existing developed areas can be affordably controlled at the same regional facilities that are sited to control future development ❍ Regional facilities provide greater opportunities for multipurpose uses such as recreational and aesthetic benefits, flood control, and wildlife ❍ Can be used to treat runoff from public streets which is often missed by on-site facilities ❍ Identifies opportunities to reduce regional stormwater pollutant loadings and provides a schedule for imple-menting appropriate controls	❍ Significant advanced watershed planning required ❍ Requires up-front financing ❍ Requires land availability and acquisition ❍ May promote "end-of-pipe" treatment mentality rather than the use of on-site controls to reduce stormwater runoff volume and the need for stormwater treatment ❍ Greater administrative responsibility for municipali-ties and local governments ❍ Some treatment practices are not appropriate for large drainage areas (swales, filter strips, media fil-ters, and oil/particle separators)

Source: Adapted from Novotny, 1995; DEP¸ 1995; Pennsylvania Association of Conservation Districts et al., 1998; WEF and ASCE, 1992.

Figure 3-2 On-site and Regional Stormwater Treatment Approaches



Source: Adapted from Novotny, 1995.

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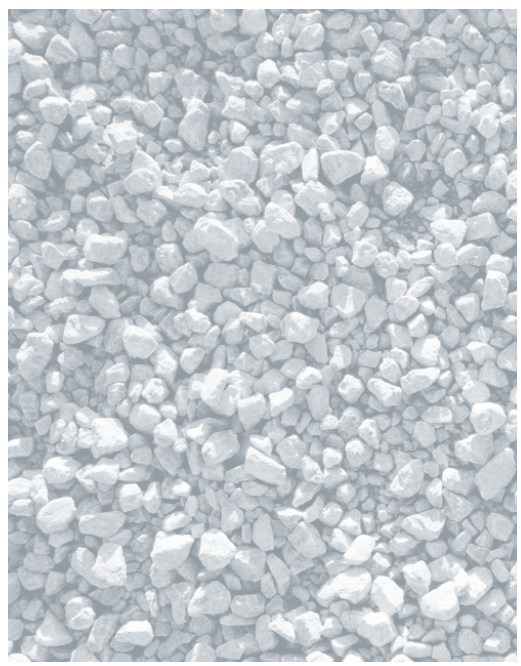
Chapter 4
Site Planning and Design



Volume 1: Background

Chapter 4

Site Planning and Design

4.1 Introduction

Careful site planning at the outset of a project is the most effective approach for preventing or reducing the potential adverse impacts from development. Site planning is a preventive measure that addresses the root causes of stormwater problems. Effective site layouts and designs that preserve natural features as well as natural hydrologic and water quality functions can limit water quality impacts and the need for costly structural stormwater controls, thereby reducing the costs of development. Other potential benefits of effective site planning include preservation of open space, enhanced aesthetic and recreational value, reduced downstream flooding, and enhanced land values.

Site planning and design is a complex process involving a variety of considerations such as zoning regulations (e.g. setbacks, Floor Area Ratio allowances, allowable building density, and height restrictions) and impacts to traffic, wetlands, and the environment. Site planning is undertaken by the developer or project proponent in conjunction with local and/or state review agencies, typically local Planning, Zoning, and Inland Wetlands Commissions and, in some instances, the Connecticut Department of Environmental Protection (DEP) or federal agencies such as the U.S. Army Corps of Engineers. Due to the complexities of site planning and design, the most effective site planning process occurs through a collaborative effort between developers and the review agencies before and throughout the review process.

This chapter addresses recommended site planning concepts and practices that can be incorporated into the design of new projects to provide water quality and quantity benefits and reduce the need for or size of structural stormwater controls. This chapter does not address comprehensive land use planning (master planning, zoning, open space, conservation easements, etc.) which is beyond the scope of this Manual. However, the site planning concepts and practices presented in this chapter should be implemented through existing local land use ordinances and state regulations and programs. Local and state review agencies should encourage the implementation of these practices through the site plan review process. In many instances, communities may need to re-evaluate local codes and ordinances to effectively promote the use of the practices described in this chapter. These design concepts are encouraged by DEP, as well as by the Connecticut Department of Public Health (DPH) for protection of water supplies in public drinking water supply watershed areas.

4.2 Site Planning and Design Concepts

The concepts presented in this section are central to effective site planning and design for stormwater management and environmental resource protection. Each of these concepts is based on the fundamental objective of preserving a site's natural hydrologic conditions. As discussed in Chapter Two, the hydrologic conditions and pollutant removal functions of a site can be altered significantly as a result of development. The traditional approach to site drainage has been to remove runoff from the site as quickly and efficiently as possible through the use of storm sewers and structural stormwater conveyances, and to provide detention facilities to manage increases in peak flows. This approach severely reduces the natural hydrologic and water quality functions of the site and contributes to the adverse environmental impacts discussed in Chapter Two.

A guiding principle of effective site planning is to preserve pre-development hydrologic conditions such as:

- *Runoff volume and rate*
- *Groundwater recharge*
- *Stream baseflow*
- *Runoff water quality*

This can be accomplished through a number of techniques that should be integrated into the site planning and design process wherever possible. These techniques are described in the following sections of this chapter. In collaboration with DEP's NPS Program, the University of Connecticut Cooperative Extension System's Nonpoint Education for Municipal Officials (NEMO) Project offers assistance to Connecticut municipalities in implementing these site planning and design strategies. (See Additional Information Sources at the end of this chapter or visit http://www.nemo.uconn.edu).

Designing the Development to Fit the Terrain

Developments that are designed to "fit the terrain" of the site require significantly less grading and soil disturbance than those that are designed without regard for the existing topography. Road patterns should match the landform by placing roadways parallel to contour lines where possible. In doing so, natural drainageways can be constructed along street rights-of-way, thereby reducing the need for storm pipes. Open space development, allowable in many municipalities, can help preserve large natural areas and open space as well as make it possible to design around topographical constraints.

Limiting Land Disturbance Activities

Land disturbance activities such as clearing and grubbing, excavation, and grading result in erosion of exposed soils, increased sediment loadings, as well as increased volumes of runoff from a site. Limiting the land area disturbed by development can only be addressed comprehensively at the site planning level (Schueler, 1995). Land disturbance activities should be limited to only those areas absolutely necessary for construction purposes, in keeping with the natural features of the site, and should be clearly delineated in the field prior to construction. Land disturbance activities in proximity to wetlands, watercourses, steep slopes, and other sensitive resource areas should be avoided, or minimized if they cannot be avoided. Areas outside the disturbed zone should retain natural vegetation. This approach is more successful on larger lots where large areas of undeveloped land can be preserved. The successful application of this approach is more difficult and less practical on small lots in heavily developed areas (NJDEP, 2000).

Reducing or Disconnecting Impervious Areas

Reducing and disconnecting impervious surfaces are effective methods for preserving pre-development hydrology. Reducing impervious coverage on a site directly limits the adverse impacts associated with impervious coverage. On a watershed basis, reductions in impervious coverage contribute directly to the ecological health of streams and receiving waters, as described in Chapter Two. Impervious surfaces that are not directly connected to the drainage collection system contribute less runoff and smaller pollutant loads than hydraulically connected impervious surfaces. Isolating impervious surfaces also promotes infiltration of stormwater runoff. Specific techniques for reducing or disconnecting impervious areas for road and lot development are described in **Section 4.3 Alternative Site Design.**

Preserving and Utilizing Natural Drainage Systems

The goal of traditional drainage design, to collect and convey stormwater runoff from the site as efficiently as possible, is in direct conflict with the objectives of water quality design, which is to slow down and attenuate runoff to allow filtration, infiltration, biological uptake, and settling of pollutants. Natural drainage features such as vegetated swales and channels and natural micro-pools or depressions should be preserved or incorporated into the design of a site to take advantage of their ability to infiltrate and attenuate flows and filter pollutants. The use of natural overland drainage features such as stabilized swales, where soil and hydraulic conditions allow, and the discharge of stormwater in a diffuse manner from level spreaders should be encouraged as an alternative to traditional storm sewer systems. Consistent with this approach is to design roads and parking areas at higher elevations in the landscape and locate existing swales along back lot lines within drainage easements (Pennsylvania Association of Conservation Districts et al., 1998). Natural low areas or depressions in the landscape should be preserved where possible to maintain infiltration of runoff in these areas similar to pre-development conditions.

Providing Setbacks and Vegetated Buffers

Setbacks and vegetated buffers provide protection of adjacent natural resources from areas of intensive development. A setback is the regulated area between the development and a protected area such as a wetland. A vegetated buffer is an area or strip of land of permanent undisturbed vegetation adjacent to a water body or other resource. Buffers protect resources from adjacent development during construction and after development by filtering pollutants in runoff, protecting water quality and temperature, providing wildlife habitat, screening structures and enhancing aesthetics, and providing access for recreation. Characteristics such as width, target vegetation, and allowable uses within buffers are managed to ensure that the goals designated for the buffer are achieved (Center for Watershed Protection, 1998b). Buffers along watercourses also serve to function as greenways that provide for connectivity of open space areas, allowing the movement of wildlife and the opportunity for passive recreation. The dual benefits that buffers provide for the protection of water quality from stormwater runoff and the creation of greenways are extremely important and complementary. **Table 4-1** summarizes the benefits that can be achieved by buffer systems.

As a general rule, one hundred feet of undisturbed upland along a wetland boundary or on either side of a watercourse is recommended as a minimum buffer width depending on the slope and sensitivity of the wetland or watercourse. A conceptual three-zone

Table 4-1 Benefits of Watercourse Buffers

Benefit	
Reduce nuisance drainage problems and complaints	Prevent disturbance of steeps slopes
Allow for lateral movement of streams	Mitigate stream warming
Provide flood control	Preserve important terrestrial habitat
Reduce stream bank erosion	Supply conservation corridors
Increase property values	Maintain essential habitat for amphibians
Enhance pollutant removal	Fewer barriers to fish migration
Provide opportunities for Greenways	Discourage excessive storm drain enclosures/channel hardening
Provide food and habitat for wildlife	Provide space for stormwater treatment practices
Protect associated wetlands	Allow for future restoration

Source: Adapted from Center for Watershed Protection, 1998a.

stream buffer system designed for protecting aquatic resources while providing flexibility for development is shown in **Figure 4-1** (Center for Watershed Protection, 1998a, adapted from Welsh, 1991). Each zone can have designated functions, width requirements, and management requirements.

Minimizing the Creation of Steep Slopes

Development or disturbance of steep slopes creates the potential for erosion and significant sediment loadings in the absence of effective stabilization measures. Development destroys vegetation, root systems, and soil structure (Pennsylvania Association of Conservation Districts et al., 1998). Although the definition of steep depends on soil characteristics and erodibility, slopes steeper than 10 percent, or even flatter slopes with highly erodible soils, typically require stabilization. The area and duration of disturbance on steep slopes should be minimized. Soil stabilization measures should be implemented in accordance with local erosion and sedimentation control ordinances, as well as the *Connecticut Guidelines for Soil Erosion and Sediment Control* (Connecticut Council on Soil and Water Conservation and the Connecticut Department of Environmental Protection, 2002).

Maintaining Pre-Development Vegetation

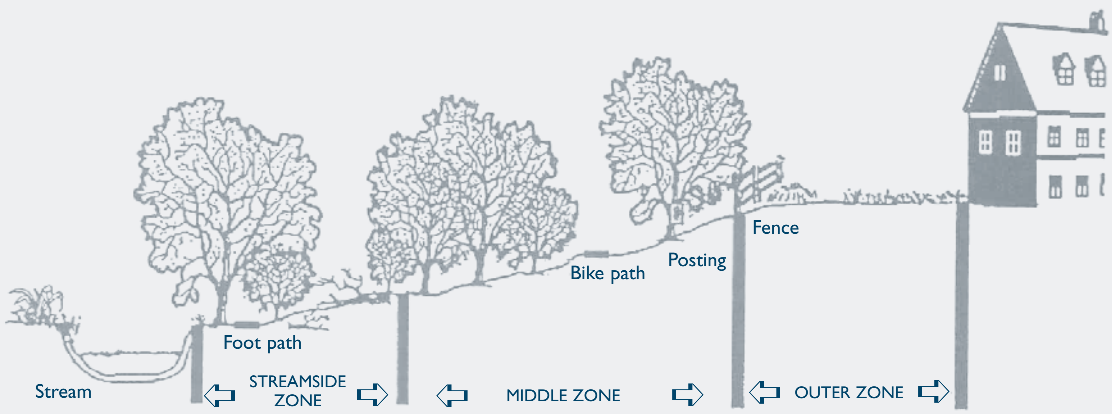
Pre-development vegetation should be maintained to the extent possible, especially on streambanks that might otherwise be cleared for view enhancement. Vegetation intercepts rainfall and promotes evapotranspiration, thereby reducing the volume of runoff from a site. In addition to providing erosion control, trees also provide shade to minimize thermal impacts to surface waterbodies. Trees and other vegetation can be incorporated into a site by planting additional native vegetation, clustering tree areas, and conserving existing native vegetation. Wherever practical, trees should be incorporated into community open space, street rights-of-way, parking lot islands, and other landscaped areas.

4.3 Alternative Site Design

A variety of innovative site design practices have been developed as an alternative to traditional development to control stormwater pollution and protect the ecological integrity of developing watersheds. These alternative site design practices are based on the concepts described in the previous section, such as reducing site imperviousness and disturbed areas, preserving natural site features, and promoting infiltration through the use of natural vegetated conveyances. Research has demonstrated that alternative site design can reduce impervious cover, runoff volume, pollutant loadings, and development costs when compared to traditional development (Center for Watershed Protection, 2000). **Table 4-2** summarizes the documented benefits of alternative site design.

Several factors have limited the widespread application of alternative site design principles in Connecticut and other parts of the country. Alternative site design is a relatively new concept, dating back only to the early 1990s, and involves fundamental changes to development practices that

Figure 4-1 Typical Three-Zone Urban Buffer System



Source: Center for Watershed Protection, 1998a (adapted from Welsh, 1991).

are typically dictated by a complex mix of local zoning, subdivision, and building ordinances. Typical conventional development rules are often inflexible and restrict development options regarding site plan parameters. Consumer demand for wide streets, long driveways, expansive parking lots, and large-lot subdivisions, whether perceived or actual, has also limited the use of alternative site design concepts by the development community.

This Manual encourages the use of alternative site design practices to the extent that local development rules will allow, to achieve the benefits listed in **Table 4-2**, as well as to reduce the need for and size of end-of-pipe stormwater treatment. However, the Manual also recognizes that communities may need to re-evaluate local codes and ordinances to overcome these challenges and effectively promote the widespread use of alternative site design practices. Recommended sources of information on how communities can modify local development rules to reduce impervious cover, conserve natural areas, and prevent stormwater pollution are provided at the end of this chapter.

A unique demonstration project is currently underway in Connecticut to compare the stormwater runoff quantity and quality emanating from traditional and alternative residential development sites. The Jordan Cove Urban Watershed Monitoring Project is a paired-watershed monitoring study funded, in part, through the Connecticut Department of Environmental

Table 4-2 Benefits of Alternative Site Design

Benefit	
Protection of surface water quality	A more aesthetically pleasing and naturally attractive landscape
Reduction of stormwater pollutant loads	Safer residential streets
Reduction of soil erosion during construction	More sensible locations for stormwater facilities
Reduced development construction costs	Easier compliance with wetland and other resource protection regulations
Increases in local property values and tax revenues	Neighborhood designs that provide a sense of community
More pedestrian friendly neighborhoods	Urban wildlife habitat through natural area preservation
More open space for recreation	Protection of sensitive forests, wetlands, and habitats

Source: Adapted from Center for Watershed Protection, 1998a.

Protection and by the U.S. Environmental Protection Agency's Section 319 National Monitoring Program (NMP). The study is examining differences in runoff quantity and quality from three watersheds located in Waterford, Connecticut, including an existing control watershed with traditional residential development and a newly constructed residential development split into two distinct neighborhoods, one with traditional subdivision design and the other with open space design and a variety of Low Impact Development practices. Post-construction flow and water quality monitoring will continue for three years after build-out. The results of this are expected to provide quantitative, real-world comparisons of the benefits and challenges of alternative site design.

A number of recommended alternative site design practices are described in the following sections. These practices are loosely organized into two categories:

- *Streets and Parking Lots*
- *Lot Development*

4.3.1 Streets and Parking Lots

These practices address the design of streets, parking lots, and other impervious surfaces associated with vehicular traffic in residential and commercial areas.

Reducing Street Widths

Many residential streets are wider than necessary. Reducing the width of streets can reduce impervious surfaces in a watershed. Other benefits of narrower streets include reduced clearing and grading impacts, reduced vehicle speeds (i.e., "traffic calming"), lower maintenance costs, and enhanced neighborhood character. Reducing or eliminating on-street parking can reduce road surfaces and overall site imperviousness by 25 to 30 percent (Sykes, 1989). In some areas, curbing can be eliminated to encourage sheet flow and facilitate the use of vegetated roadside swales. Eliminating curbing in residential and rural areas with nearby vernal pool habitat also allows amphibian migration across roads. An alternative to eliminating curbing is the use of Cape Cod curbing, which allows amphibians to climb.

Residential streets should be designed for the minimum required pavement width needed to support travel lanes, on-street parking, as well as emergency, maintenance, and service vehicle access. Residential street widths should be based on the following four variables:

- **Traffic Volume:** *A simple rule of thumb regarding traffic volume is the fewer the vehicles, the narrower the road may be. Many communities require a minimum width of 32 to 34 feet of pavement or two, adjacent 16- to 17-foot travel lanes for all roads. Research shows that 20-to 24-foot road widths (two 10- to 12-foot travel lanes) are adequate for most local roads.*

Table 4-3 Minimum Residential Roadway Width Guidelines

Terrain Classification[1]	Level			Rolling			Hilly		
Development Density[2]	Low	Med	High	Low	Med	High	Low	Med	High
Right of Way Width (ft)	50	60	60	50	60	60	50	60	60
Pavement Width (ft)	20-24	28	36	20-24	28	36	28	28	36
Sidewalks and Bicycle Paths (ft)	0	4	5	0	4	5	0	4	5

Source: Guidelines for Residential Subdivision Street Design, Institute of Transportation Engineers, Washington DC, 1993, in University of Connecticut, Transportation Institute, Technology Transfer Center Fact Sheet.

1Terrain Classification: Level – grade of 0% to 8%, Rolling – >8% to 15%, Hilly – >15%

2Development Density: Low – 2 or fewer dwelling units/acre, Med – >2 to 6 dwelling units/acre, High – more than 6 dwelling units/acre

- **Design Speed:** *Slower design speeds allow for narrower road widths. Local residential roads should be designed to provide safe access to homes. Research indicates that as residential streets widen, accidents per mile per year increase exponentially and that the safest residential street width is 24 feet (Swift et al., 1998).*

- **Lot Width:** *As a general rule, large lots with long front yards require less on-street parking since large lots by their very nature have enough area to accommodate on-site parking. Roads serving large lots do not have to be designed with on-street parking lanes and therefore can be narrower.*

- **Parking Needs:** *The need for on-street parking is often used to justify wider residential streets. Roads designed to provide overflow parking from adjacent lots require one or two additional parking lanes. However, not all roads are designed to accommodate on-street parking and therefore do not require additional parking lanes.*

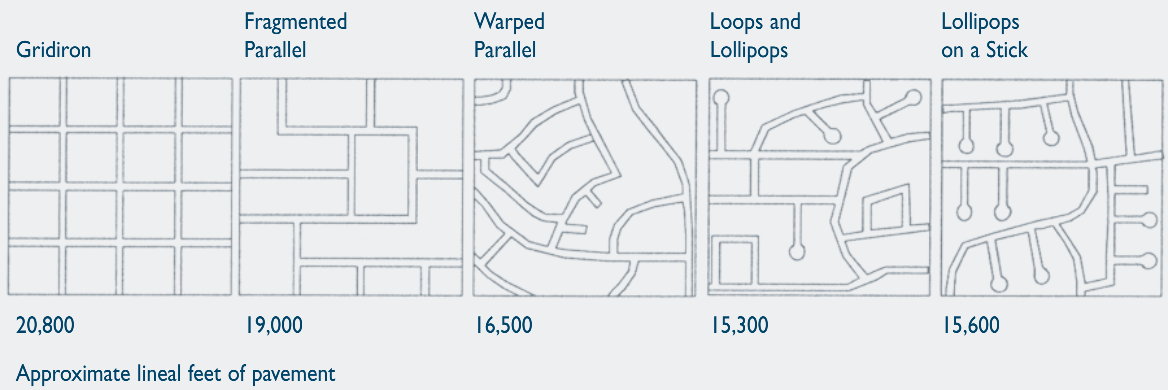
(NEMO Technical Paper #9, Roads, Gibbons 1998a): The standard 50- to 60-foot right-of-way width is recommended to provide adequate emergency access and parking. However, the paved portion of the right-of-way should be minimized to the extent possible. **Table 4-3** presents minimum roadway width guidelines for residential subdivision street design.

Reducing Street Lengths through Alternative Street Layout

Street lengths and, therefore, total site imperviousness can be reduced through alternative street and subdivision layouts. **Figure 4-2** illustrates how alternate layouts can reduce roadway impervious surfaces by up to 26 percent.

No single street layout is appropriate for all residential development. Roadway layout is highly dependent on site topography, density, traffic volume, and overall subdivision design. Residential areas with low traffic volume and minimal topographical relief have the most flexibility in design. In Connecticut, a majority of residential subdivisions use the "loops and lollipops" and "lollipops on a stick" configurations. These road layout designs utilize cul-de-sacs, loops, and short feed streets to accommodate the contours and natural features of a site. Open space development, a compact form of development that concentrates density on one portion of the site in exchange for reduced density elsewhere, also lends itself to reduced street lengths. Grid-based street layouts tend to have relatively longer overall street lengths. The exception is traditional neighborhood design, which incorporates community open space, a variety of housing types, and mixed land uses in a single project to emulate the characteristics of smaller, older communities (Center for Watershed Protection, 1998a).

Figure 4-2 Alternative Street Layout



Source: Prince George's County, Maryland, 1999 (adapted from ULI, 1980).

Alternative Cul-de-sac Design

Cul-de-sacs have a large bulb located at the closed end of the street to enable emergency and service vehicles to turn around without having to back up. Traditional cul-de-sacs utilize a large-radius, paved turnaround that can dramatically increase the imperviousness of a residential subdivision. Alternatives to this traditional design include turnaround bulbs with smaller radii and the use of a landscaped island (i.e., rain garden or bioretention area) in the center of the cul-de-sac to collect rainwater from the end of the roadway.

Reducing the radius of a typical cul-de-sac turnaround from 40 to 30 feet can reduce impervious coverage by nearly 50 percent (Schueler, 1995). A 30-foot radius will accommodate most vehicles and reduce pavement. Cul-de-sac bioretention islands have been used successfully in various parts of the country, including a demonstration subdivision in Waterford, Connecticut. These islands can be landscaped with low maintenance perennials or shrubs appropriate for the soil and moisture conditions. Bioretention and rain gardens are discussed later in this chapter. If a cul-de-sac island is used, the cul-de-sac radius should allow for a minimum 20-foot wide road. To make turning easier, the pavement at the rear center of the island may be wider (Metropolitan Council, 2001). **Figure 4-3** illustrates these cul-de-sac design concepts.

Reducing the Use of Storm Sewers

The use of swales and other vegetated open channels should be encouraged in residential streets, parking lots, and back yards in place of conventional storm drain systems. Open vegetated channels provide the potential for infiltration and filtering runoff from impervious surfaces, as well as groundwater recharge and reduced runoff volume. In addition to the water quality benefits that open vegetated channels provide, these systems are also significantly less expensive to construct than conventional storm drain systems. The use of vegetated drainage swales in lieu of conventional storm sewers may be limited by soils, slope, and development density. In many cases, subdivision ordinances discourage or prohibit the use of open vegetated channels for roadside drainage due to concerns over inadequate drainage, maintenance issues, pavement stability, and nuisance insects (if water is allowed to stand for longer than 7 to 10 days). This practice requires educating local citizens and public works officials who expect runoff to disappear quickly after a rainfall event (Pennsylvania Association of Conservation Districts et al., 1998).

Reducing Parking Lot Size

Parking lots are the largest component of impervious cover in most commercial and industrial land uses (Center for Watershed Protection, 1998a). The number of parking spaces at a site is determined by local parking ratios which dictate the minimum number of spaces per square foot of building, dwelling units, persons, or similar measure. Parking ratios are typically set as minimums, not maximums, thereby allowing for excess parking. In addition, local parking codes often require standard parking stall dimensions to accommodate larger vehicles. A recent parking study conducted for the Northwestern Connecticut Council of Governments and Litchfield Hills Council of Elected Officials demonstrated that, in most cases, demand for parking is less than what is required by zoning, while more parking than required by zoning is provided. Big box retail parking lots typically have more excess parking than for any other land use (*Draft Northwest Connecticut Parking Study, Fitzgerald & Halliday, Inc. 2002*).

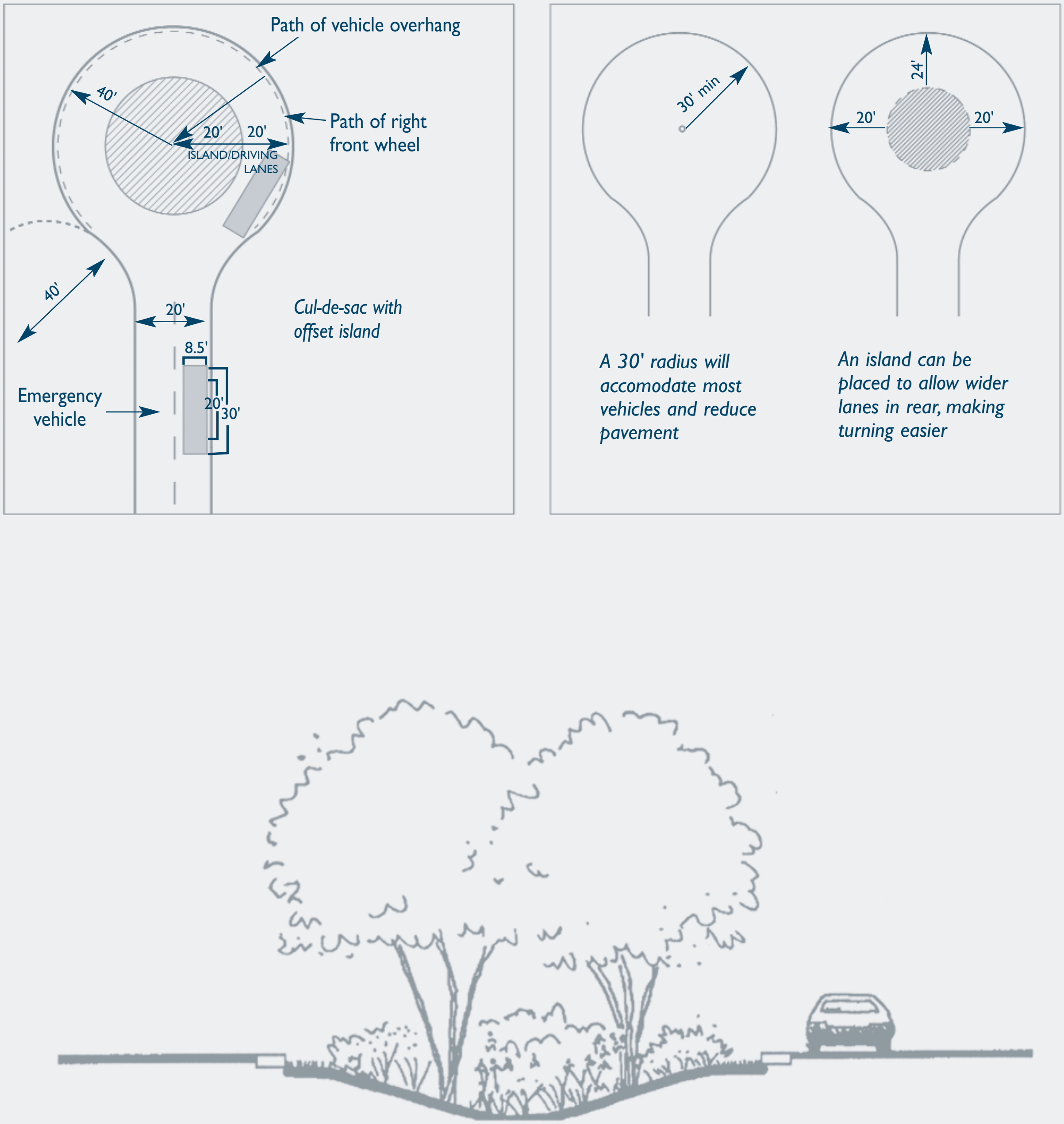
Reducing minimum parking requirements, establishing or enforcing maximum parking lot ratios, reducing parking stall size, and incorporating alternative internal geometry or traffic patterns through the use of one-way aisles and angled parking stalls can reduce parking lot size and impervious cover. Parking demand ratios should be based upon site-specific parking generation studies, where feasible (Metropolitan Council, 2001). Incorporation of bioretention facilities or other stormwater treatment devices (i.e., sand filters, vegetated swales, filter strips) into parking lot design features such as perimeter and median strips can further reduce pollutant loads from these areas. **Figure 4-4** is a schematic of an alternative parking lot design.

Shared parking is a similar strategy that reduces the number of parking spaces needed by allowing adjacent land uses to share parking lots. For shared parking to operate successfully, the participating facilities should be in close proximity to each other and have peak parking demands that occur at different times during the day or week (Center for Watershed Protection, 1998a). Examples of facilities with different daily peak hours and potential candidates for shared parking include professional offices, banks, and retail stores (daytime peak hours) and theaters, restaurants, and bars (evening peak hours). Use of phantom parking is also recommended. Under a phantom parking strategy, sufficient land is reserved for projected parking requirements, but only a portion of the parking area is constructed at the outset. Additional areas are paved on an as-needed basis.

Using Permeable Paving Materials

Permeable paving materials are alternatives to conventional pavement surfaces designed to increase infiltration and reduce stormwater runoff and pollutant loads. Alternative materials include modular concrete paving blocks, modular concrete or plastic lattice, cast-in-place concrete grids, and soil enhancement technologies. These practices increase a site's load bearing capacity and allow grass growth and infiltration (Metropolitan Council, 2001). Stone, gravel, and other low-tech materials can also be used as

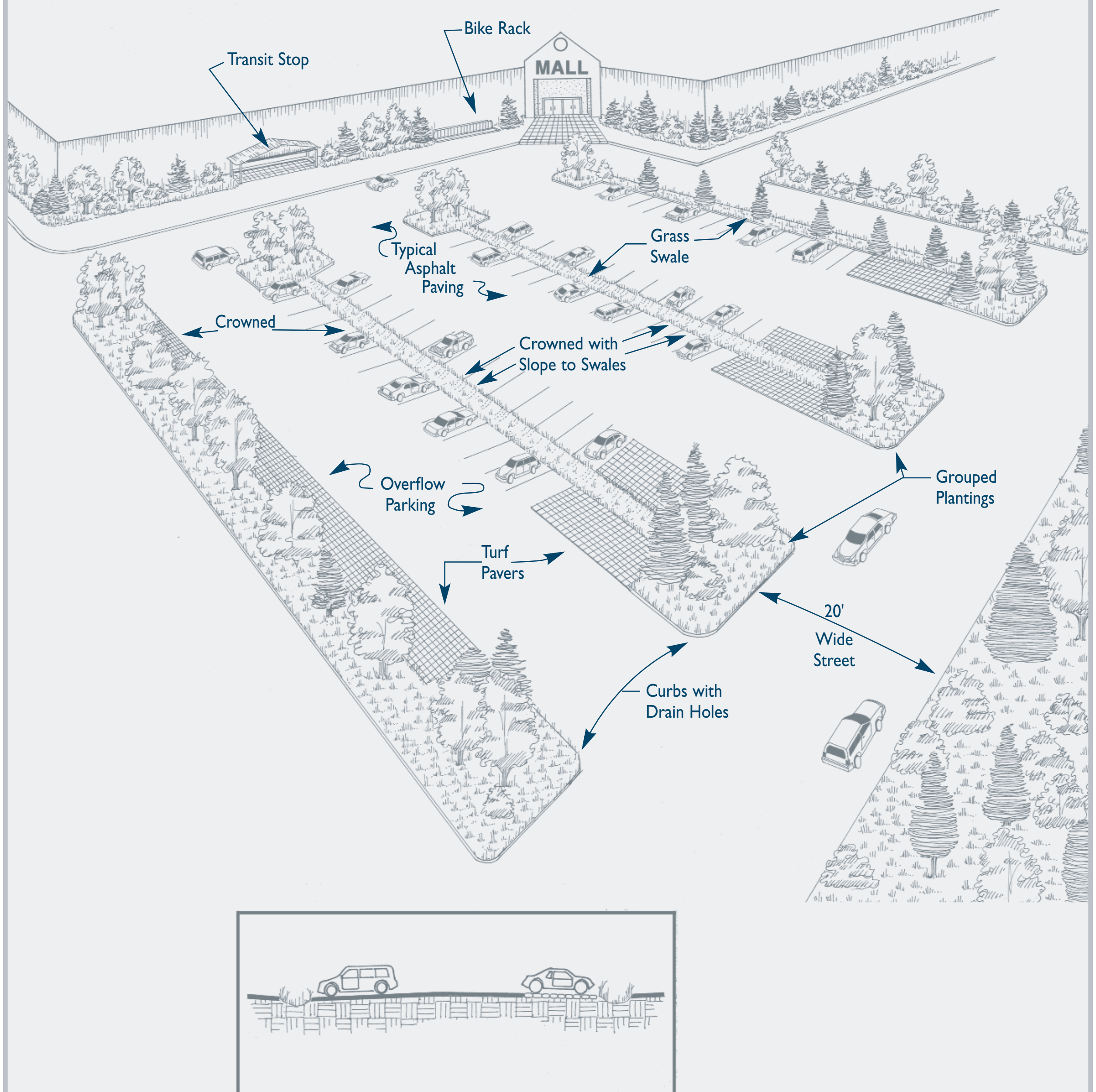
Figure 4-3 Alternative Cul-de-sac Design



Cul-de-sac infiltration island accepts stormwater from surrounding pavement. Note flat curb.

Source: Metropolitan Council, 2001 (adapted from Schueler, 1995 and ASCE, 1990).

Figure 4-4 Alternative Parking Lot Design Schematic



Source: Metropolitan Council, 2001 (adapted from Robert W. Droll, ASLA, in Wells 1994).

alternatives for low traffic applications such as driveways, haul roads, and access roads.

Porous asphalt or concrete, also known as porous pavement, is similar to conventional asphalt but formulated to have more void space for greater water passage through the material. Traditionally, porous pavement has had limited application in cold climates such as Connecticut due to the potential for clogging as a result of sand application. Porous pavement has been successfully used for some parking lot applications in New England where the underlying soils are sufficiently permeable. One example is a parking lot demonstration project at Walden Pond State Reservation in eastern Massachusetts.

While permeable paving materials can make sense in many parking lot designs, site-specific factors such as accessibility, soils, maintenance, and long-term performance must be carefully considered. Permeable paving materials are most appropriate in areas of low traffic volume (e.g., generally less than 500 average daily trips or ADT) such as roadside rights-of-way, emergency access lanes, delivery access routes, residential driveways, and overflow parking. Chapter Eleven of this Manual contains additional siting and design guidance for permeable pavement materials.

4.3.2 Lot Development

These alternative design practices address the size, shape, density, and appearance of residential development.

Maintaining Pre-Development Vegetation

Pre-development vegetation should be maintained to the extent possible. Vegetation intercepts rainfall and promotes evapotranspiration, thereby reducing the volume of runoff from a site. Trees and other vegetation can be incorporated into a site by planting additional vegetation, clustering tree areas, and conserving native vegetation. Wherever practical, trees should be incorporated into community open space, street rights-of-way, parking lot islands, bioretention areas, and other landscaped areas.

Open Space Development

Open space development, also known as conservation or cluster development, can reduce the amount of impervious area for a given number of lots. Open space development is a compact form of development that concentrates density in one portion of the site in exchange for reduced density elsewhere (Center for Watershed Protection, 1998a). Planners have advocated open space development for many years for community design, preservation of rural character, or creation of affordable housing. However, it has only recently been identified as a site planning practice for reducing imperviousness and for environmental protection. Open space design is most effective for reducing impervious cover when used in conjunction with narrower streets and other alternative site design practices. Studies have shown that open space designs can reduce impervious cover from 15 to 50 percent when compared to conventional subdivision designs, particularly if narrow streets are utilized (NEMO, 1999). Open space designs can generally achieve significant reductions in impervious cover for most residential zones, although only minor reductions occur in areas with 1/8-acre lots and smaller (Center for Watershed Protection, 1998a).

The benefits of open space development are summarized in **Table 4-4**. In particular, this Manual encourages the use of open space development as an alternative to conventional subdivision layout to:

- *Reduce overall site imperviousness and associated stormwater impacts*
- *Avoid development in sensitive areas of a site*
- *Locate stormwater treatment facilities within the open space*

Historically, there have been several barriers to the widespread use of open space development in Connecticut, primarily due to poorly worded "cluster zoning" adopted by many communities in the 1960s and 1970s. Smaller lot sizes and compact development can be perceived as less marketable, and prospective homebuyers may have concerns over management of community open space. Other common obstacles have included opposition from adjacent residents due to concerns about density, traffic congestion, and property values. More recent studies have demonstrated that many of these concerns can be addressed through thoughtful site design and clear local ordinances (Center for Watershed Protection, 1998a). Conservation subdivisions have also been shown to have marketing and sales advantages, as buyers prefer lots close to or facing protected open space. Conservation subdivisions have also been shown to appreciate faster than counterparts in conventional developments (NEMO, 1999). The Jordan Cove Urban Watershed Monitoring Project in Waterford, Connecticut is expected to provide additional insight into the benefits of open space development. Recommended sources of additional information on open space and conservation development are listed at the end of this chapter.

Reducing Building Setbacks

Reducing building setbacks can reduce impervious cover. Reducing front yard setbacks results in shorter driveways. Narrower side yard setbacks may result in narrower lots and shorter road lengths, provided that narrower lots do not result in greater overall density of development. Flexible setbacks and frontage

Table 4-4 Benefits of Open Space Development

Benefit	
Reduction of site imperviousness	Reduces the cost of future public services needed by the development
Reduction of stormwater runoff and pollutant loads	Can increase future residential property values
Reduction of pressure to encroach on resource and buffer areas	Reduces the size and cost of stormwater quantity and quality controls
Reduction of soil erosion potential due to reduced site clearing	Concentrates runoff where it can be most effectively treated
Reserves large portion of site as green space	Provides a wider range of feasible sites to locate stormwater quality controls
Reserves portion of site in open space dedicated to passive recreation	Provides wildlife habitat
Reduces capital cost of development	Increases sense of community and pedestrian movement
Provides compensation for lots that may be lost when land is reserved for resource protection and stream buffers	Can support other community planning objectives such as farmland preservation, community preservation, and affordable housing

Source: Adapted from Schueler, 1995.

requirements have been shown to provide attractive and unique residential subdivisions (Center for Watershed Protection, 1998a). Despite these benefits, the use of flexible setback and frontage distances for reduction in impervious cover has not been widespread. Setbacks and frontage requirements are dictated by local ordinances to satisfy various community goals including uniformity of lot size, safety, and traffic congestion. As a result, concerns regarding parking, safety issues, subsurface sewage disposal systems, livability, and marketability are often impediments to relaxed setbacks and frontage widths. Reducing building setbacks is most readily accomplished along low-traffic streets where traffic congestion and noise are not a problem (Pennsylvania Association of Conservation Districts et al., 1998).

Limiting Sidewalks to One Side of the Street

Subdivision codes often require sidewalks on both sides of the street, as well as a minimum sidewalk width and distance from the street. Limiting sidewalks to one side of the street can reduce total site imperviousness. A sidewalk on one side of the street may suffice in low traffic areas where safety and pedestrian access would not be significantly affected. Sidewalk plans, similar to roadway plans, should be developed by towns to ensure that sidewalks move people efficiently from their homes to services and attractions (NEMO, 1999a). Reducing sidewalk widths, separating them from the street with a vegetated area, and grading sidewalks away from rather than towards the street can reduce impervious area and stormwater runoff.

Reducing Hydraulic Connectivity of Impervious Surfaces

Impervious surfaces that are not directly connected to the drainage collection system contribute less runoff and smaller pollutant loads than hydraulically connected impervious surfaces. Isolating impervious surfaces also promotes infiltration and filtration of stormwater runoff. Strategies for accomplishing this include:

- *Disconnecting roof drains and directing flows to vegetated areas or infiltration structures (swales, trenches, or drywells)*
- *Directing flows from paved areas such as driveways to stabilized vegetated areas*
- *Breaking up flow directions from large paved surfaces*
- *Encouraging sheet flow through vegetated areas*
- *Locating impervious areas so they drain to natural systems, vegetated buffers, natural resource areas, on-lot bioretention areas, or permeable soils*

(Prince George's County, Maryland, 1999).

Modifying/Increasing Runoff Travel Time

The peak discharge rate and volume of stormwater runoff from a site are influenced by the runoff travel time and hydrologic conditions of the site. Runoff travel time can be expressed in terms of "time of concentration" which is the time required for water to flow from the most distant point to the downstream outlet of a site. Runoff flow paths, ground surface slope and roughness, and channel characteristics affect the time of concentration. Site design techniques that can modify or increase the runoff travel time and time of concentration include:

- *Maximizing overland sheet flow*
- *Increasing and lengthening drainage flow paths*
- *Lengthening and flattening site and lot slopes (although may conflict with goal of minimizing grading and disturbance)*
- *Maximizing use of vegetated swales*

(Prince George's County, Maryland, 1999).

4.4 Low Impact Development Management Practices

Low Impact Development (LID), a relatively new concept in stormwater management pioneered by Prince George's County, Maryland and several other areas of the country, is a site design strategy that employs many of the concepts and practices already described in this chapter. The goal of LID is to maintain or replicate predevelopment hydrology through the use of small-scale controls integrated throughout the site (U.S. EPA, 2000). Site design techniques such as those described above are one component of the LID approach. The other major component of the LID approach is the use of micro-scale integrated management practices to manage runoff as close to its source as possible. This involves strategic placement of lot-level controls to reduce runoff volume and pollutant loads through infiltration, evapotranspiration, and reuse of stormwater runoff.

The appropriateness of LID practices is highly dependent on site conditions. Soil permeability, slope, and depth to water table and bedrock are physical constraints that may limit the use of LID practices at a site. Community perception and local development rules may also present obstacles to the implementation of LID practices, as described previously in this chapter. Although alternative site design and LID practices may not replace the need for conventional stormwater controls, the economical and environmental benefits of LID practices are well documented (U.S. EPA, 2000). LID practices described in the following sections include:

- *Vegetated Swales, Buffers, and Filter Strips*
- *Bioretention/Rain Gardens*
- *Dry Wells/Leaching Trenches*
- *Rainwater Harvesting*
- *Vegetated Roof Covers (Green Roofs)*

The main feature that distinguishes these practices from conventional structural stormwater controls is scale. These small systems are typically designed as off-line systems that accept runoff from a single residential lot or portions of a lot, as opposed to large multiple-lot or end-of-pipe controls. The following sections contain summary descriptions of these small-scale LID practices. The design sections of this Manual contain more detailed guidance for similar, larger-scale stormwater treatment practices such as bioretention, infiltration, and filtration systems.

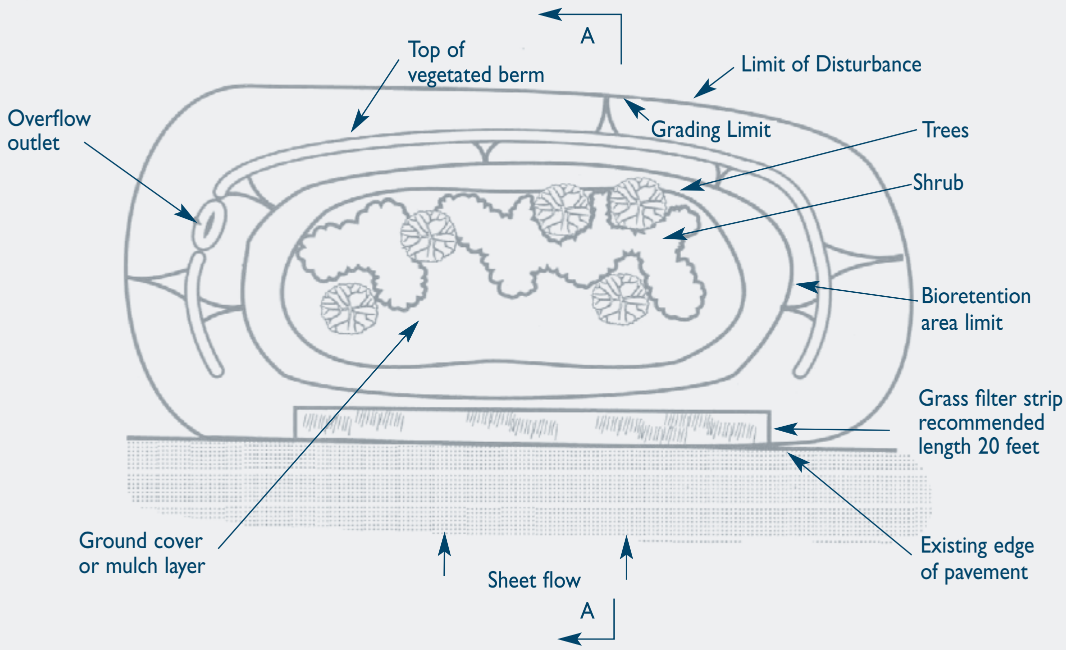
4.4.1 Vegetated Swales, Buffers, and Filter Strips

Vegetated swales, buffers, and filter strips are vegetative practices that can be incorporated into a site to maintain predevelopment hydrology. These practices are adaptable to a variety of site conditions, are flexible in design and layout, and are relatively inexpensive (U.S. EPA, 2000). Vegetated swales can provide both water quantity and quality control by facilitating stormwater infiltration, filtration, and adsorption. Vegetated buffers are strips of vegetation (natural or planted) around sensitive areas such as wetlands, watercourses, or highly erodible soils (Prince George's County, Maryland, 1999). Similarly, filter strips are typically grass or close-growing vegetation planted between pollutant source areas and downstream receiving waters or wetlands. Filter strips are commonly located downgradient of stormwater outfalls and level spreaders to reduce flow velocities and promote infiltration/filtration. Chapter Eleven provides additional design guidance on these vegetative practices.

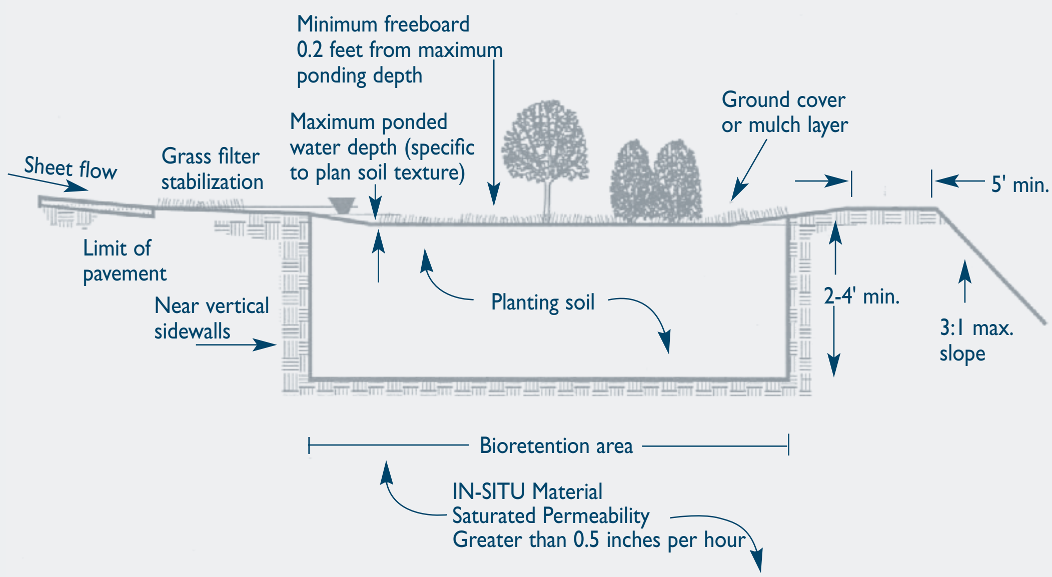
4.4.2 Bioretention/Rain Gardens

Bioretention is a practice to manage and treat stormwater runoff by using a specially designed planting soil bed and planting materials to filter runoff stored in a shallow depression (Prince George's County, Maryland, 1999). Bioretention areas are composed of a mix of functional elements, each designed to perform different functions in the removal of pollutants and attenuation of stormwater runoff. Bioretention removes stormwater pollutants through physical and biological processes, including adsorption, filtration, plant uptake, microbial activity, decomposition, sedimentation, and volatilization (U.S. EPA, 2000). The major components of a bioretention system include:

Figure 4-5 Functional Elements of a Bioretention Facility



Plan view (not to scale)



Section A-A (not to scale)

Source: Prince George's County, Maryland, 1999.

- *Pretreatment area (optional)*
- *Ponding area*
- *Ground cover layer*
- *Planting soil*
- *In-situ soil*
- *Plant material*
- *Inlet and outlet controls*

Figure 4-5 is a schematic of a typical bioretention facility depicting each of these functional elements. Bioretention facilities are most effective if they receive runoff as close as possible to the source and are incorporated throughout the site (Pennsylvania Association of Conservation Districts et al., 1998).

Rain gardens are a small-scale form of bioretention that can be incorporated into a variety of areas in new and existing developments, including:

- *Residential yards*
- *Street median strips*
- *Road shoulder rights-of-way*
- *Parking lot islands*
- *Under roof downspouts*

Rain gardens serve as a functional landscape element, combining shrubs, grasses, and flowering perennials in depressions that allow water to pool for only a few days after a rain (Metropolitan Council, 2001). The soil absorbs and stores the rainwater and nourishes the garden vegetation. Rain gardens are an effective, low-cost method for reducing runoff volume, recharging groundwater, and removing pollutants. **Figure 4-6** shows examples of several rain garden designs for residential lots.

4.4.3 Dry Wells/Leaching Trenches

Dry wells are small excavated pits or trenches filled with aggregate which receive clean stormwater runoff primarily from building rooftops. Dry wells function as infiltration systems to reduce the quantity of runoff from a site. Dry wells treat stormwater runoff through soil infiltration, adsorption, trapping, filtering, and bacterial degradation (Prince George's County, Maryland, 1999). **Figure 4-7** shows a schematic of a typical dry well. The use of dry wells is applicable for small drainage areas with low sediment or pollutant loadings, and where soils are sufficiently permeable to allow reasonable rates of infiltration and the groundwater table is low enough to allow infiltration. Chapter Eleven contains additional design guidance for dry wells.

4.4.4 Rainwater Harvesting

Rain is a renewable resource and is abundant in Connecticut. Rainwater harvesting can be used to supply water for drinking, washing, irrigation, and landscaping. It generally involves five main components: catchment, conveyance, purification, storage, and distribution. Catchment areas are most commonly roofs, while conveyance is via gutters and roof leaders. Rainwater is stored in either rain barrels or cisterns (water tanks). Purification for reuses other than drinking and washing primarily involves directing the initial flow of runoff, which contains the highest levels of accumulated contaminants, away from the storage system. Finally, distribution is through garden hoses or typical plumbing, depending on the application.

For the purposes of this manual, rainwater harvesting can be used to retain a portion of stormwater runoff during rain events and release it during dry periods such that the total volume of runoff is reduced. However, there are additional benefits to harvesting rainwater. Rainwater is generally very soft compared to other sources, as it does not come in contact with soil, and therefore contains low levels of dissolved salts and minerals. This makes it preferable for irrigation, gardening, and landscaping. If used for drinking and washing, soft water is less taxing on plumbing and water tanks.

Rain barrels are designed to retain small volumes of runoff for reuse for gardening and landscaping. Rain barrels are applicable to residential, commercial, and industrial sites and can be incorporated into a site's landscaping plan. Multiple rain barrels can be used to retain larger volumes of runoff. The size of the rain barrel is a function of rooftop surface area and the design storm to be stored. For example, one 42-gallon rain barrel provides 0.5 inch of runoff storage for a rooftop area of approximately 133 square feet (Prince George's County, Maryland, 1999). **Figure 4-8** shows a typical rain barrel.

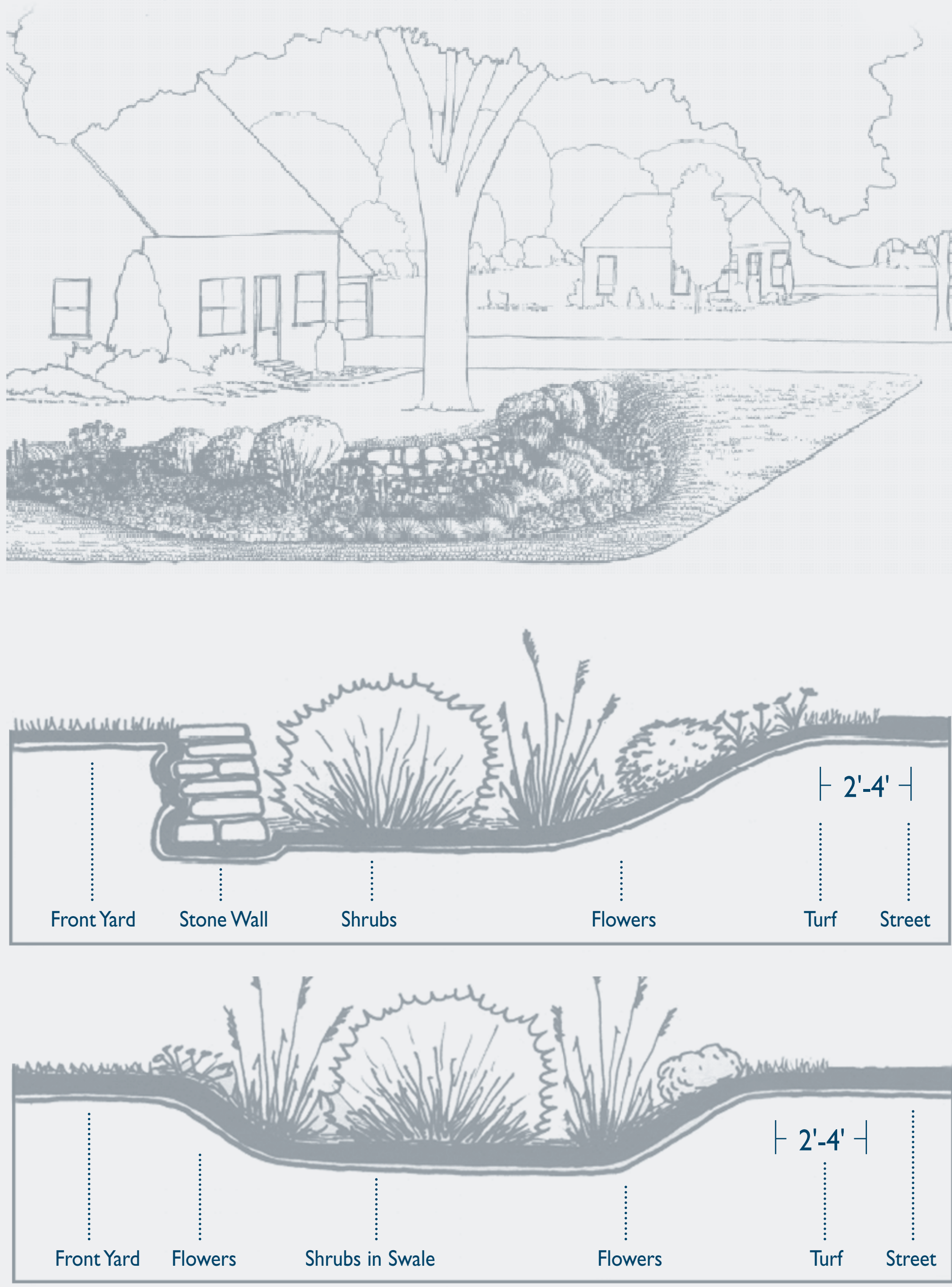
Cisterns store larger quantities of rooftop stormwater runoff and may be located above or below ground. Cisterns can also be used on residential, commercial, and industrial sites. Pre-manufactured cisterns come in a variety of sizes from 100 to 10,000 gallons. However, even larger concrete cisterns may be constructed in place for large industrial, commercial, and public uses. From a stormwater management perspective, the use of cisterns for commercial development where proposals include high levels of impervious cover, particularly in highly urbanized areas, should become a more commonly implemented stormwater management practice in the future.

General design considerations for rain barrels and cisterns include:

- *Equip rain barrels with a drain spigot with a garden hose threading*

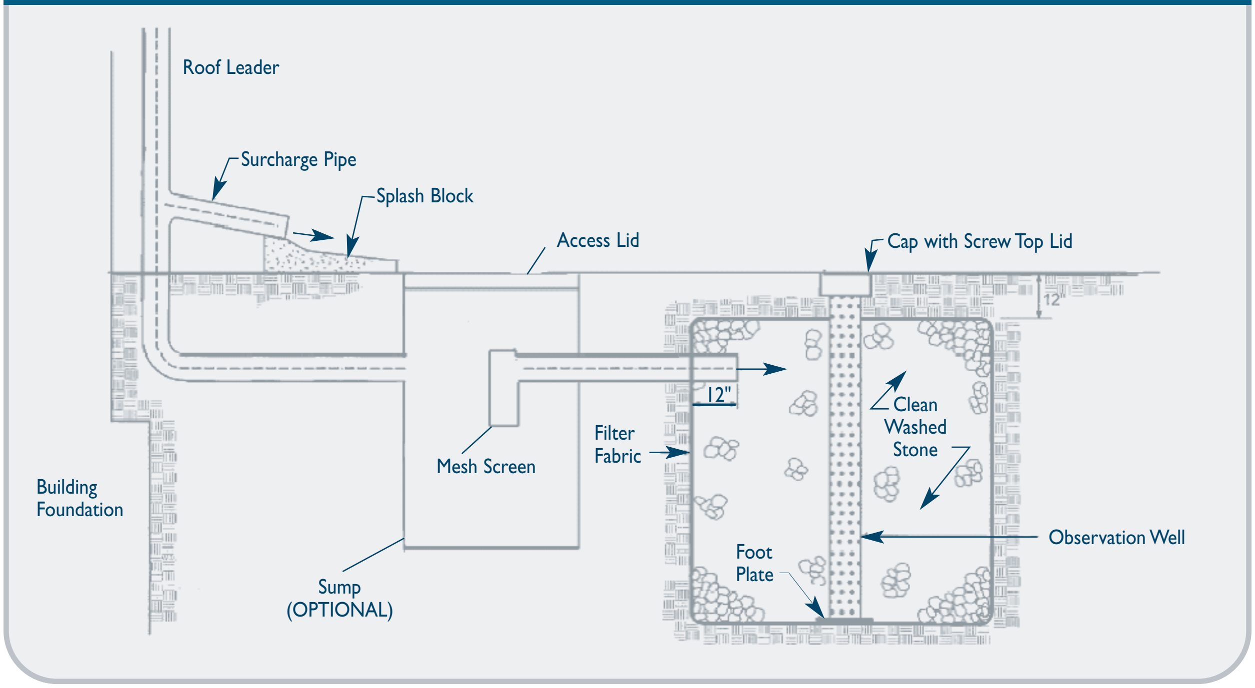
Figure 4-6 Residential Rain Gardens

Typical Residential Rain Garden (With and Without Masonry Wall)



Source: Metropolitan Council, 2001 (Adapted from Nassauer et al., 1997) and Low Impact Development Center (www.lowimpactdevelopment.org), 2001.

Figure 4-7 Schematic of Typical Dry Well



Source: Adapted from NYDEC, 2001.

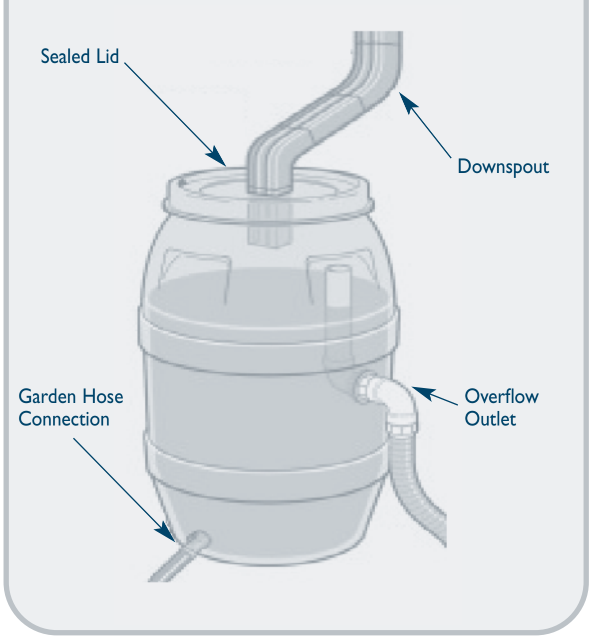
- *Use a tight-fitting, light-blocking lid to keep children and animals out of the water, stop the development of algae, and limit access to standing water by mosquitoes and other nuisance insects. Alternatively, a small mesh screen could be used over the hole in the barrel/cistern to limit mosquito-breeding potential*
- *Use a roof washer (collection and disposal of the first flush of water from a roof) to catch accumulated debris and divert the first flush of runoff away from rain barrels or cisterns*
- *Use an overflow device to direct excess water away from a building's foundation when the tank is full*
- *Monitor cistern intakes and overflows for blockage*
- *Locate cisterns as close to supply and demand as possible*
- *Size storage volume based on seasonal rainfall data and anticipated water requirements*
- *For drinking water supply, purification using ultraviolet light, ozonation, chlorination, reverse osmosis, and carbon filters can be used*

4.4.5 Vegetated Roof Covers

Vegetated roof covers, also referred to as "green roofs", are layers of vegetation installed on building rooftops. Green roofs are an effective means for reducing urban stormwater runoff by replacing impermeable rooftops with permeable, vegetated surfaces. Rainwater is either intercepted by vegetation and evaporated to the atmosphere or retained in the substrate before being returned to the atmosphere through transpiration and evaporation. Several examples of vegetated roof installations are shown in **Figure 4-9**.

The green roof is a multilayered, constructed roof system consisting of a vegetative layer, media, a geotextile layer, and a synthetic drain layer. Green roofs have been used extensively in Europe and are becoming more common in the United States. A variety of green roof designs exist. The simplest consists of a light system of drainage and filtering components and a thin soil layer, which is installed and planted with drought-resistant herbaceous vegetation (Metropolitan Council, 2001). This type of system is called an extensive system. More complex green roof systems such as roof gardens built to accommodate trees, shrubs, and recreational access are called intensive systems. **Figure 4-10** is a schematic of the functional components of the simpler extensive vegetated roof system.

Table 4-8 Typical Rain Barrel



Source: Adapted from urbangardencenter.com (D&P Industries, Inc., 2001).

Recently developed, modular green roof systems are available for new installations and building retrofits. These systems consist of interlocking modules containing plants that are shipped to the roof site for installation. The modules can be removed or replaced, thereby facilitating roof maintenance and repair.

Green roofs are effective in reducing total runoff volume. For example, simple vegetated roof covers with approximately 3 inches of substrate can reduce annual runoff by more than 50 percent in temperate climates (U.S. EPA, 2000). Green roofs not only retain rainwater, but also moderate the temperature of the water and act as natural filters for any of the water that happens to runoff (Green Roofs for Healthy Cities Website, 2001). Green roofs in urban areas offer a variety of other benefits such as:

- *Reduced energy costs by providing building insulation*
- *Conservation of land that would otherwise be required for stormwater controls*
- *Improvement of air quality by reducing carbon dioxide levels and binding airborne particulates*
- *Air temperature regulation and reduction of the "urban heat island" effect*
- *Sound insulation*
- *Improved aesthetics and views from other buildings*
- *Habitat for birds*

Design considerations for vegetated roof covers include structural and load-bearing capacity, plant selection, waterproofing and drainage, and water storage (Metropolitan Council, 2001). Limitations of green roof systems include:

- *Damage to waterproofing materials may result in serious roof damage*
- *Can be expensive to design and construct*
- *Sloped-roof applications require additional erosion control measures*
- *Higher maintenance than conventional roof*

Additional Information Sources

The UConn Cooperative Extension System's Nonpoint Education for Municipal Officials (NEMO) Project. In collaboration with DEP's NPS Program, the NEMO Project provides NPS management education and technical assistance to Connecticut municipalities free of charge. NEMO's goal is to help municipalities reduce NPS pollution by understanding natural resource based planning and how to implement it (http://www.nemo.uconn.edu).

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Figure 4-9 Examples of Vegetated Roof Installations

Source: Chicago City Hall (Roofscapes, Inc. 2001)

Source: Mashantucket Pequot Museum and Research Center, Mashantucket, Connecticut (Photo courtesy of American Hydrotech, Inc. 1998)

Source: Fencing Academy of Philadelphia (Charlie Miller, Roofscapes, Inc. 1998)

Source: Nonpoint Education for Municipal Officials (NEMO)

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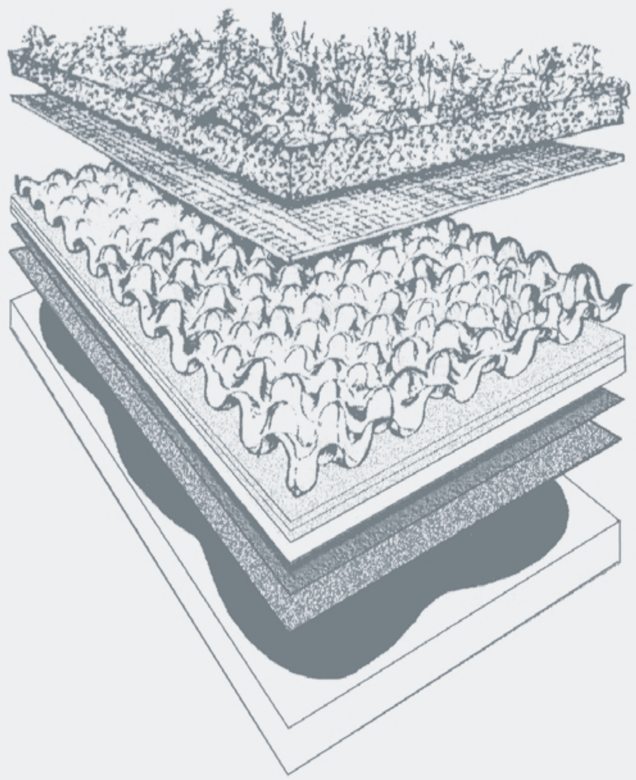
Figure 4-10 Schematic of a Typical Vegetated Roof System



Source: Metropolitan Council, 2001 (original source Miller 1998 and American Hydrotech).

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Chapter 5
Source Control Practices and Pollution Prevention

Chapter 5

Source Control Practices and Pollution Prevention

5.1 Introduction

Controlling the sources of pollution and preventing pollutant exposure to stormwater are important management techniques that can reduce the amount of pollutants in stormwater and the need for stormwater treatment. Source control practices and pollution prevention can include a wide variety of management techniques that address stormwater and other nonpoint sources of pollution. Most are typically non-structural, require minimal or no land area, and can be implemented with moderate cost and effort as compared to structural treatment practices. In addition to management actions, source control and pollution prevention also include education and outreach.

Developing awareness of potential sources of pollution and ways to modify behavior in order to reduce both the amount of available pollutant and the volume of stormwater runoff are key elements in this approach to stormwater management. This chapter discusses the following source control and pollution prevention practices that are commonly applied in municipal, industrial, commercial and residential settings:

- *Street and Parking Lot Sweeping*
- *Roadway Deicing/Salt Storage*
- *Storm Drainage System Maintenance*
- *Other Road, Highway, and Bridge Maintenance*
- *Illicit Discharge Detection and Elimination*
- *Commercial and Industrial Pollution Prevention Plans*
- *Animal Waste Management*
- *Lawn Care and Landscaping Practices*
- *Model Stormwater Ordinances*
- *Public Education*

5.2 Municipal Practices

5.2.1 Street and Parking Lot Sweeping

Removal and proper disposal of sediment and debris from paved surfaces reduces the exposure of these materials to stormwater washoff and subsequent pollutant export to receiving waters. The reported effectiveness of street sweeping varies considerably among sources (e.g., EPA, 1983; Bannerman, 1999) and is particularly dependent upon the type of sweeper used.

Sweeper Type

Mechanical Broom Sweepers: These are the oldest and most common type of sweeper used for municipal roadway cleaning. They work like a broom and dustpan to pick of particles and only remove large debris. Mechanical broom sweepers are relatively ineffective at removing particles smaller than 60 microns. In addition, the broom action may actually break larger particles into smaller ones, which are more difficult to pick up (Schwarze Industries, Inc., 2001).

Vacuum Sweepers: Vacuum sweepers work in a manner comparable to household vacuum cleaners. Typically, a broom head pushes debris toward a suction inlet or vacuum. Traditional vacuum sweepers use a water-based dust suppression system, but still exhaust a high level of particulates into the atmosphere while in operation (Schwarze Industries, Inc., 2001).

Regenerative Air Sweepers: Regenerative air sweepers use a closed-loop, cyclonic effect to clean. Air is constantly recirculated or regenerated in the unit. It is blasted onto the pavement on one side of the sweeper head, picks up debris as it travels across the width of the head, and is suctioned up on the vacuum inlet on the other side of the sweeper head. Regenerative air sweepers use water for dust suppression and exhaust some particulates into the atmosphere during operation.

Dry Vacuum Sweepers: Unlike water-assisted vacuum sweepers, dry vacuum sweepers use a filtration system and require no water for dust suppression. Consequently, this type of sweeper can also be used in colder weather, since freezing conditions are not an issue for operation. The internal filtration system also results in less fine-grained particulate exhaust to the atmosphere compared to the mechanical sweepers discussed above.

Sweeper Effectiveness

The improvements in sweeper technology over the past 20 years have considerably improved the capability of sweepers to pick up the fine-grained sediment particles that carry a substantial portion of the stormwater pollutant load (EPA, 2002). A study by Terrene Institute in 1998 has shown that mechanical broom sweepers and water-assisted vacuum sweepers reduce nonpoint source pollution by 5-30 percent and nutrient content by 0-15 percent. However, dry vacuum sweepers are reported to reduce non-point source pollution by 35-80 percent and nutrients by 15-40 percent. Bannerman (1999) estimates that, depending upon sweeping frequency, dry vacuum sweepers could achieve a 50-80 percent overall reduction in the annual sediment load for a residential street.

The effectiveness of pavement sweeping in reducing nonpoint source pollution in a particular area is a function of several variables including:

Street Condition: Regular pavement repair and maintenance will encourage a smooth pavement condition and texture which will reduce the amount of particulates shaken from vehicles, increase the ease of street sweeping, and reduce the amount of particulates generated from the deteriorating street surface itself.

Geographic Location: The frequency of precipitation events capable of removing particulates from the paved surface will influence the effectiveness of a sweeping program.

Sweeper Operator's Skill: Optimum pollutant removal is a function of operator control over sweeper speed, brush adjustment and rotation rate, sweeping pattern, and maneuvering around parked vehicles.

Presence of Parked Vehicles: On-street parking of vehicles during sweeping reduces overall effectiveness.

Amount of Impervious Area Devoted to Rooftop (as compared to pavement): Sweeping is obviously more effective in areas where paved surfaces are the major contributor to impervious surfaces in a watershed.

Frequency of Sweeping: More frequent sweeping should improve overall sediment load reductions, and is particularly important for streets or other paved areas with high pollutant loadings.

Type of Mechanical Sweeper Used: As discussed above, dry vacuum and regenerative air sweepers are preferable to mechanical broom and traditional water-assisted vacuum sweepers. State, municipal, commercial, and industrial facilities with street sweepers should consider upgrading to the latest sweeping technology when new equipment is purchased. A 10-year equipment replacement cycle is recommended. (EPA, 2002). In colder climates such as Connecticut, street sweeping can be effectively used during the spring snowmelt to reduce pollutant loads from road salt (see section on deicing for further information) and sand export to receiving waters. In Connecticut, the recommended minimum frequency for street sweeping is once per year as soon as possible after snowmelt and, when possible, before spring rainfall events. In urbanized areas and other areas with higher potential pollutant loadings, streets may require sweeping more than once per year.

Because of the initial capital cost and operation and maintenance costs associated with a street sweeping program, municipalities should prioritize street sweeping activities to achieve the most effective pollution prevention. In general, street sweeping is most effective in urban areas and pollutant removal rates are typically higher on residential roads than for arterial roadways (EPA, 2002). When developing a street sweeping program, more sophisticated sweepers such as dry vacuum sweepers should be used in areas of higher pollutant loading, and these areas should also be considered for more frequent sweeping. Municipalities can also improve the effectiveness of street sweeping programs by enforcing construction site erosion controls, especially the use of anti-tracking pads to minimize excess sediment on paved surfaces; and developing and enforcing regulations for alternate side parking during cleaning operations, litter control, and trash and refuse storage and disposal, especially yard debris.

Disposal of Sweepings

Street sweepings may contain low levels of chemical compounds associated with stormwater runoff such as lead, sodium and compounds associated with asphalt and motor oils. Street sweepings are also likely to contain debris such as leaves, broken glass, and small pieces of metal.

Temporary Storage of Street Sweepings: Temporary storage of street sweepings prior to reuse or disposal should be located in an area where the sweepings will not wash into wetlands or watercourses. Acceptable temporary storage sites include:

- *an empty salt storage shed*
- *a municipal site where sand and salt are normally handled*
- *a paved area that is more than 100 feet from a wetland or watercourse*

Street sweepings should not be combined with sand and debris collected from catch basins. Material removed from catch basins may have higher concentrations of pollutants. Prior to reuse, materials such as trash, leaves and debris should be removed from the street sweepings by screening or other appropriate method and such materials should either be disposed of at a permitted solid waste facility, recycled (e.g. aluminum cans) or composted (e.g. leaves).

Limitations on Reuse of Street Sweepings without Testing: It is acceptable to reuse street sweepings without analyzing the concentration of chemical compounds in the following ways:

- *as fill in road construction projects where the sweepings are used below the paved surface or in the median strip of a divided highway*
- *as aggregate in concrete or asphalt*
- *as daily cover on a permitted landfill*

Limitations on Reuse of Street Sweepings with Testing: Properly tested street sweepings may be used for fill material on an industrial or commercial property, provided the testing for both heavy metals and semivolatile organic compounds, at a frequency of approximately one sample per 500 cubic yards of street sweepings, shows concentrations below the residential direct exposure standards established in the Remediation Standard Regulations found in Appendix A to Sections 22a-133k-1 through 22a-133k-3 in the Regulations of Connecticut State Agencies ("RCSA"). Alternatively, properly tested street sweepings may be reused at other sites in accordance with the regulations for reuse of polluted soil pursuant to Section 22a-133k-2(h) RCSA.

No Use on Residential Property: Street sweepings, regardless of testing status, are not recommended for use on residential property because they may contain broken glass or other sharp debris.

Disposal at Permitted Solid Waste Facility: Street sweepings that are not used in the manner described above should be disposed of at a permitted solid waste facility.

5.2.2 Roadway Deicing/Salt Storage

Salts, sand, gravel and other materials are applied to roadways during the winter months in Connecticut. The salts and other deicing materials discussed below lower the melting point of ice and are applied to reduce icing on roadways. Sand and gravel are applied to roadways to increase traction during and after adverse winter weather conditions.

Common Deicers

Sodium Chloride: Also called rock salt, this is the most commonly used deicing product due to its low cost and effectiveness. Sodium chloride will work at temperatures as low as –7°F, but is most effective at 10-15°F.

Calcium Chloride: This salt is a more expensive deicing agent than sodium chloride. However, it works at temperatures as low as -60°F, but is most effective at approximately -25°F.

Calcium Magnesium Acetate (CMA): CMA is a frequently used alternative to sodium chloride. It is made from dolomitic limestone treated with acetic acid. It is reported to work at temperatures as low as -5°F, but is most effective at approximately 20-25°F (Ohrel, 2000).

Blended Products: These new deicing materials consist of various combinations of sodium, calcium, magnesium, and chloride, as well as other constituents, but typically are lower in sodium chloride (Lucas, 1994).

Environmental concerns related to roadway deicing materials include:

- *Damage to vegetation growing adjacent to roadways receiving salt application (See plant list in **Appendix A** for a list of more salt-resistant vegetation for roadway plantings)*
- *Residues of chloride ions on the roadway surface that may contaminate groundwater resources*
- *Other substances in deicing chemicals that act to prevent caking (i.e., sodium ferrocyanide) or prevent corrosion may be toxic to human, animal, and fish life (FWHA, 1999)*

Table 5-1 compares the environmental effects of several common roadway deicers as reported in a 1993 study by the Michigan Department of Transportation and cited by Ohrel (2000). Other potential environmental impacts associated specifically with sodium chloride include temporary reductions in soil microbes, sensitivity of certain deciduous trees, and secondary components (3-5 percent of road salt composition)

Table 5-1 Comparison of Environmental Effects of Common Roadway Deicers

Media	Sodium Chloride ($NaCl$)	Calicum Chloride ($CaCl_2$)	CMA ($CaMgC_2H_3O_2$)	Sand (SiO_2)
Soils	Cl complexes release heavy metals; Na can break down soil structure and decrease permeability	Ca can exchange with heavy metals, increase soil aeration and permeability	Ca and Mg can exchange with heavy metals	Gradually will accumulate on soil
Vegetation	Salt spray/splash can cause leaf scorch and browning or dieback of new plant growth up to 50 feet from road; osmotic stress can result from salt uptake; grass more tolerant than trees and woody plants		Little effect	Accumulates on and around low vegetation
Groundwater	Mobile Na and Cl ions readily reach groundwater, and concentration levels can increase in areas of low flow temporarily during spring thaws. Ca and Mg can release heavy metals from soil			No known effect
Surface Water	Can cause density stratification in small lakes having closed basins, potentially leading to anoxia in lake bottoms; often contain nitrogen, phosphorus, and trace metals as impurities, often in concentrations greater than 5 ppm		Depletes dissolved oxygen in small lakes and streams when degrading	No known effect
Aquatic Biota	Little effect in large or flowing bodies at current road salting amounts; small streams that are end points for runoff can receive harmful concentrations of Cl; Cl from NaCl generally not toxic until it reaches levels of 1,000-36,000 ppm.		Can cause oxygen depletion	Particles to stream bottoms degrade habitat

Source: Adapted from Ohrel, 2000.

including nitrogen, phosphorus, and metals that may be released to receiving waters (Ohrel, 2000). The Federal Highway Administration (FHWA, 1999) reports that surface water resources are not as susceptible as groundwater to impacts from deicing chemicals due to the blending and dilution of runoff entering surface waters. However, the impact to surface waters depends on the amount of deicing chemical applied, the intensity of subsequent precipitation events, and the ecological health and use of the receiving water (FHWA, 1999).

Storage

Proper placement and storage of deicing chemicals is also important for preventing contamination of surface water runoff. **Table 5-2** summarizes recommendations for minimizing environmental impacts related to deicer, particularly salt, storage. Storage facilities should not be located within 250 feet of a well utilized for public drinking water, within a mapped Level A aquifer protection area, or within a mapped 100-year floodplain. They should also be at least 100 feet from wetlands or watercourses. Storage piles should be covered. This reduces the loss of deicing compounds from stormwater runoff and subsequent contamination of surface waters. Operationally, this reduces caking and clumping, making it easier to load and apply (EPA, 2002). Ideally, a structure should be provided for storage. At a minimum, all stockpiles should be covered with an appropriately sized, weighted tarp. All stockpile storage should be on impermeable pads.

Application

Proper application of deicers is important for both traffic safety and to prevent increased concentrations in roadway runoff. **Table 5-2** summarizes a few key suggestions for minimizing environmental impacts related to deicer, particularly salt, application. The Connecticut Department of Transportation (DOT) has developed guidelines for mixtures and application rates of sodium chloride and sand on state-maintained roadways in Connecticut (DOT, 1999). The mixture and application rates are a function of the type of roadway (i.e., two-lane versus multi-lane) and the weather and roadway conditions. Connecticut DOT also uses roadway sensors on some roads to create a thermal mapping of roadway temperatures and truck-mounted sensors that read both ambient and pavement temperatures. Since there may be differences between air and pavement surface temperatures, the use of sensors allows Connecticut DOT to tailor application rates to roadway conditions.

Training of public works personnel or others responsible for deicing in the proper storage and most effective application of deicers is also an important pollution prevention technique. The Salt Institute has developed a "Sensible Salting" training program (The Salt Institute, 2002) that focuses on maximizing the deicing properties of sodium chloride for roadway safety while protecting the environment. The program addresses:

- *Personnel training*
- *Equipment*
- *Calibration of spreaders*
- *Use of automatic controls*
- *Adequate, covered storage*
- *Proper maintenance around storage areas*
- *Environmental awareness for salt applicators*

Public drinking water supplies (potable surface water and groundwater) are particularly susceptible to contamination from roadway deicers. Reduced application rates or alternative deicers (calcium chloride or CMA) are recommended in environmentally sensitive areas such as public water supply watersheds, aquifer protection areas, and areas of high groundwater recharge. Road crews should be familiar with identified sensitive areas that may be affected by roadway deicer application.

Snow Disposal

"Waste" snow accumulated from plowing activities can be a source of contaminants and sediment to surface waters if not properly located. DEP has developed guidance for the disposal of post-plowing snow (DEP, 1995). The "waste" snow piles should be located in upland areas only and should not be located in the following locations:

- *Storm drainage catch basins*
- *Storm drainage swales*
- *Stream or river banks that slope toward the water*
- *Freshwater or tidal wetlands or immediately adjacent areas*

Table 5-2 Recommendations to Reduce Deicer Impacts

Activity	Recommendations
Storage	○ Salt storage piles should be completely covered, ideally by a roof and, at a minimum, by a weighted tarp, and stored on impervious surfaces ○ Runoff should be contained in appropriate areas ○ Spills should be cleaned up after loading operations. The material may be directed to a sand pile or returned to salt piles ○ Avoid storage in drinking water supply areas, water supply aquifer recharge areas, and public wellhead protection areas
Application	○ Application rate should be tailored to road conditions (i.e., high versus low volume roads) ○ Trucks should be equipped with sensors that automatically control the deicer spread rate ○ Drivers and handlers of salt and other deicers should receive training to improve efficiency, reduce losses, and raise awareness of environmental impacts
Other	○ Identify ecosystems such as wetlands that may be sensitive to salt ○ Use calcium chloride and CMA in sensitive ecosystem areas ○ To avoid over-application and excessive expense, choose deicing agents that perform most efficiently according to pavement temperature ○ Monitor the deicer market for new products and technology

Source: Adapted from Ohrel, 2000.

- *Within 100 feet of private drinking water supply wells*
- *Within 500 feet of public drinking water supply wells*
- *Public drinking water supply watershed areas*

5.2.3 Storm Drainage System Maintenance

In order to maintain their intended function, stormwater drainage and treatment systems should be inspected at least annually. Deterioration of any part of the system that threatens the structural integrity of the facility should be immediately repaired. Inspection and cleaning of catch basins and stormwater inlets preserves the sediment-trapping function of these devices and also prevents sediment, trash, and other pollutants present in the storm drain system from reaching receiving waters. Removal of sediment and decaying debris from catch basin sumps yields aesthetic and water quality benefits including reduction of foul odors, suspended solids, bacteria, and the load of oxygen demanding substances (EPA, 1999; EPA, 2002). Pitt (1979, 1984) found that cleaning catch basins in urban areas twice a year reduced the loads of total solids and lead in urban runoff by 10 percent and 25 percent, respectively. This maintenance schedule also reduced loads of chemical oxygen demand (COD), total Kjeldahl nitrogen, total phosphorus, and zinc by 5 percent to 10 percent (Wisconsin Department of Natural Resources, 1994).

Catch basins and other stormwater structures that accumulate sediment should be cleaned at least annually. The cleaning should include both removal of sediment from the sump and removal of any trash or debris from the grate. Additional maintenance is recommended in the fall to remove trash, leaves, and other debris. In rural areas and areas that experience significant accumulation of leaves, the recommended fall maintenance should be performed after leaf fall and before the first snowfall. In addition, areas with higher pollutant loadings or discharging to sensitive water bodies should also be cleaned more frequently (WEF and ASCE, 1998). More frequent cleaning of drainage systems may also be needed in areas with relatively flat grades or low flows since they may rarely achieve sufficiently high flows for self-flushing (Ferguson et al., 1997). Deviations from these recommended frequencies may be warranted based on field evaluation of actual sediment and debris accumulation rates, including identification and prioritization of structures that may require more or less frequent cleaning.

In addition to catch basin cleaning, storm drainage system maintenance should include removal of debris from surface basins used for stormwater management (Washington, 2000). The design sections of this Manual contain additional guidance on maintenance of stormwater treatment practices.

Polluted water or sediment removed from the storm drainage system must be disposed of properly. Before disposal, a detailed chemical analysis of the material should be performed to determine proper methods for storage and disposal (EPA, 1999).

Stormwater drainage systems located on private property, but subject to regulatory review and permitting, should be required to have similar operation and maintenance plans to protect receiving waters.

5.2.4 Other Road, Highway, and Bridge Maintenance

The following operation and maintenance practices for roads, highways, and bridges can further reduce stormwater pollutant loadings:

- *Develop an overall inspection program to ensure that general maintenance is performed on urban runoff and nonpoint source pollution control facilities.*
- *The use of chemicals such as soil stabilizers, dust palliatives, sterilants, and growth inhibitors should be limited to the best estimate of optimum application rates. All feasible measures should be taken to avoid excess application and consequent intrusion of such chemicals into surface runoff.*
- *Use techniques such as suspended tarps, vacuums, or booms to reduce, to the extent practicable, the delivery to surface waters of pollutants used or generated during bridge maintenance (e.g., paint, solvents, scrapings).*
- *Maintain retaining walls and pavements to minimize cracks and leakage.*
- *Repair potholes.*
- *Inspect silt fences and replace deteriorated fabrics and wire connections. Properly dispose of deteriorated materials.*
- *Renew riprap areas and reapply supplemental rock as necessary.*
- *Repair/replace check dams and brush barriers; replace or stabilize straw bales as needed.*
- *Regrade and shape berms and drainage ditches to ensure that runoff is properly channeled.*
- *Seed and fertilize, seed and mulch, and/or sod damaged vegetated areas and slopes.*
- *Apply seed and mulch where bare spots appear, and replace matting material if deteriorated.*
- *Ensure that culverts and inlets are protected from siltation.*

- *Inspect all permanent erosion and sediment controls on a scheduled, programmed basis.*
- *Ensure that energy dissipators and velocity controls to minimize runoff velocity and erosion are maintained.*

5.2.5 Illicit Discharge Detection and Elimination

Illicit discharges are non-stormwater flows that discharge into the stormwater drainage system. Failing septic systems, wastewater connections to the storm drain system, and illegal dumping are among the types of illicit discharges that can occur. Depending on the source, an illicit discharge may contain a variety of pollutants that can impact both human health and the aquatic environment. Identifying and eliminating these discharges is an important means of pollution source control in a stormwater drainage system.

This section provides a brief description of several common types of illicit discharges, techniques for illicit discharge detection, and public education and regulatory measures for preventing illicit discharges.

Failing Septic Systems

Septic systems are on-site wastewater disposal systems that provide a means of treating domestic wastewater in areas where public sanitary sewers are not available. After separating the solids from the wastewater stream, the septic system discharges the effluent into the ground. A failing septic system discharges effluent into the ground at concentrations that exceed water quality standards. Systems can fail for a number of reasons including unsuitable soil conditions, lack of or improper maintenance, or improper design and installation (EPA, 2002). Failing systems, as well as properly functioning septic systems in some instances, can be significant sources of nutrients, especially nitrogen, and microbial pathogens to both surface water and groundwater. Effluent that pools on the ground surface can be transported by runoff and enter nearby storm drainage systems and surface waters.

Detection of individual failing septic systems typically requires detailed on-site inspection. However, the presence of odors and isolated areas of very green grass or pooling on the ground surface are typical indicators of a failing system. Detection of optical brighteners and the use of color infrared (CIR) aerial photography are two field screening techniques that can be used (EPA, 2002). Optical brighteners are fluorescent white dyes that are used as additives in laundry soaps and detergents and are commonly found in domestic wastewater. The presence of optical brighteners can be detected by placing cotton pads in storm drains, pipes, or surface waters and then exposing them to ultraviolet light (Sargent and Castonguay, 1998). CIR is a relatively quick and cost-effective method that uses variations in vegetation growth or stress patterns to determine potentially failing septic systems (EPA, 2002).

Prevention of discharges from failing septic systems relies heavily on public education to inform homeowners about the need for routine septic system maintenance. Local health departments have educational materials available to assist with public education on this issue. In some cases, municipalities have instituted local ordinances with advanced design standards, mandatory pump-out schedules, required reporting of pump-out activities by private vendors, and inspection of septic systems upon property transfer (EPA, 2002).

Wastewater Connections

Untreated wastewater (e.g., process wastewater, wash waters, and sanitary wastewater) from business or commercial establishments that is discharged to the storm drainage system can introduce heavy metals, oil and grease, solids, sewage, detergents, nutrients, ammonia, chlorine and potassium (EPA, 2002). These contaminants can result in a variety of impacts to human health and the aquatic environment, including eutrophication, aquatic toxicity, reduced oxygen levels, and bacterial contamination (EPA, 2001).

Illicit wastewater discharges may be the result of inadvertent cross-connections between sanitary sewer and storm drainage systems. Floor drains, wash sinks, sump pumps, and solvent sinks are examples of drains that may be inadvertently connected to the storm drainage system as the result of poor mapping on internal facility pumping systems or incorrect sewer mapping (EPA, 2002). In some cases, untreated wastewater may be intentionally discharged to the storm drainage system as an inexpensive or convenient alternative to proper wastewater disposal and treatment (EPA, 2002).

Detection of illicit discharges for commercial and industrial sites can occur during both the design phase and during facility operation. During construction, inspection and verification of facility piping can avoid the need for later detection and evaluation. For facilities in operation, the use of the field screening techniques, source testing protocols, and the visual inspection methods described below can identify improper connections.

Illegal Dumping

The disposal of solid wastes in an unpermitted area, the pouring of liquid wastes or placement of trash into a storm drainage system, and blowing or sweeping of landscape debris into a public right of way or a storm drainage system are common methods of illegal dumping. Runoff from areas of illegal solid waste disposal can enter the stormwater drainage system and pollute receiving waters. Liquids or solids deposited directly into the storm drainage system are also sources of potential contamination. The extent and type of pollution generated by illegal dumping and the subsequent water quality impairment depends upon the characteristics of the illicit discharge.

Most municipalities have ordinances that prohibit illegal dumping and include penalties such as fines, jail time, or community service. However, detection of illegal dumping activities requires public education and awareness to encourage reporting of suspected illegal dumping activities.

Methods of Illicit Discharge Identification

Methods for identifying illicit discharges can vary widely in the level of effort and cost required for implementation. The following field-based methods are often used to identify illicit discharges in storm drainage systems:

Testing of Dry Weather Discharges: Flows from stormwater outfalls during dry weather may indicate an illicit discharge. A combination of visual inspection and chemical analysis of dry weather discharges can aid in identifying potential discharge sources.

Visual Inspection: Examination of piping connections by either physical examination or closed-circuit camera can be used to identify possible illicit connections.

Review of Piping Schematics: Examination of architectural plans and plumbing details can reveal potential sites of improper connections.

Smoke Testing: Injection of a non-toxic vapor (smoke) into the facility plumbing system and following its path of travel can be used to locate connections.

Dye Testing: In this method, appropriate colored dyes are added into the drain water of suspect piping. Appearance of the dyed water in the storm drainage system indicates an illicit discharge. As mentioned in the discussion of septic system discharges, testing for optical brighteners can provide an indication of the presence of domestic wastewater flows.

Infrared, Aerial, and Thermal Photography: Use of aerial, infrared, and thermal photography to locate patterns of stream temperature, land surface moisture, and vegetative growth are emerging techniques to identify potential illicit discharges to stormwater systems.

(EPA, 1999; 2002). In addition to these field methods, building and plumbing codes can help to prevent potential cross-connections between storm drainage and sanitary sewer systems. Municipalities can also prioritize illicit discharge detection efforts based on building age and/or operation type. Older buildings are more likely to have cross connections or other inappropriate discharges. A possible priority system for detecting illicit discharges from businesses is as follows:

1. *Automobile-relatedbusinesses/facilities and heavy manufacturing*
2. *Printers, dry cleaners/laundries, photo processors, utilities, paint stores, chemical laboratories, construction companies, and medium to light manufacturing*
3. *Institutional facilities, private service agencies, retail establishments, and schools*

(EPA, 2002).

5.3 Industrial and Commercial Practices

5.3.1 Stormwater Pollution Prevention Plans

Commercial and industrial facilities, including institutional facilities, can potentially contribute point or nonpoint pollution to stormwater through activities associated with operations, maintenance, and storage. DEP provides general pollution prevention information applicable to a wide variety of industries as well as pollution prevention fact sheets for the following specific industries:

- *Aerospace*
- *Chemical Manufacturers*
- *Coating*
- *Dry Cleaning Businesses*
- *Fabricated Metal*
- *Fiberglass-Reinforced Composite Plastics*
- *Marine Maintenance and Repair*
- *Metal Casting*
- *Metal Manufacturing/Finishing*
- *Metal Parts Cleaning*
- *Paint Manufacturers*
- *Pesticide Applicators*
- *Pesticide Formulating*
- *Pharmaceutical*
- *Photoprocessing*
- *Radiator Service*
- *Printed Circuit Board*
- *Printing*
- *Research and Educational Institutions*
- *Steel*

(DEP, 2002). Stormwater Pollution Prevention Plans (SWPPPs) are one facet of a facility-wide approach to pollution prevention activities. SWPPPs identify potential sources of pollution and outline specific management activities designed to minimize the introduction of pollutants into stormwater. In Connecticut, commercial and industrial facilities required to register under the General Permit for the Discharge of Stormwater Associated with Commercial Activities or the General Permit for the Discharge of Stormwater Associated with Industrial Activities have specific SWPPP requirements. (See Chapter One for a discussion of stormwater regulatory programs) Although each SWPPP must be tailored to an individual facility, as well as any regulatory requirements, the following elements are typically included:

Description of Potential Pollutant Sources: This section of the plan describes potential sources of pollutants that may reasonably be expected to affect stormwater quality at the site or that may result in the discharge of pollutants from the site during dry weather. Activities (e.g., fueling, vehicle and equipment maintenance and cleaning, and loading and unloading) and materials that may be sources of stormwater pollution should be identified. This section of the SWPPP may also include a description of the site drainage showing the direction of stormwater flow, an inventory of materials exposed to precipitation, a list of spills and leaks, and a description of any monitoring done at the site.

Stormwater Management Measures and Controls: This section of the plan describes stormwater management measures and controls for the facility and a schedule for their implementation. Typical elements discussed in this section of the SWPPP include good housekeeping practices, vehicle or equipment washing, sediment and erosion control, preventive maintenance, sweeping, spill prevention and response, outside storage, employee training, non-stormwater discharges, facility inspection, and stormwater runoff management and treatment.

Comprehensive Site Compliance Evaluation: A qualified individual knowledgeable about the General Permit requirements and the objectives and contents of the SWPPP should conduct an evaluation of the site for compliance with the provisions of the SWPPP on a regular basis. The frequency of the evaluation depends on specific permitting requirements, but typically is at least annually for commercial sites and twice per year for industrial facilities in Connecticut. The evaluation should include a visual inspection of potential pollutant sources identified in the plan to determine evidence of, or potential for, pollution entering the stormwater system; an evaluation of the management measures identified in the plan to assure that they are in place and operating correctly; and visual inspection of equipment (e.g., spill response equipment) needed to implement the plan. If possible, inspections should be conducted during rainfall events and a written report of the inspection and its findings should be prepared and retained with the SWPPP.

Pollution Prevention Team: A pollution prevention team, consisting of one or more individuals, should be identified in the plan. The team will be responsible for developing, implementing, maintaining, and revising the plan.

Record Keeping: Record keeping elements in the plan should include inspections and evaluations of the site, a list of the pollution prevention team members and their assigned responsibilities, spill control and response plans, training schedules, and stormwater-related maintenance schedules (e.g., structure cleaning, sweeping, etc.), as well as stormwater quality monitoring results.

Certification: If the SWPPP is a regulatory requirement, the plan will also require certification by a professional engineer, licensed to practice in Connecticut, stating that the SWPPP meets the requirements of the General Permit.

5.4 Lawn Care and Landscaping Practices

Source control and pollution prevention techniques related to landscaping and gardening activities rely on public education and awareness. The use of alternative landscaping techniques and judicious use of fertilizers and pesticides in landscaping and gardening require voluntary cooperation from the public, business owners, and landscaping professionals. While municipalities can establish landscaping practices for their public works or other departments that perform landscaping functions, public education is the primary method for encouraging private homeowners to adopt more environmentally friendly landscape and gardening practices. The UConn Cooperative Extension System's Residential Water Quality Program has educational workshops and materials to assist with this public education (http://www.nemo.uconn.edu).

5.4.1 Xeriscaping and General Landscape Management

Xeriscaping is landscaping to minimize water usage ("xeri" is the Greek prefix meaning "dry") and incorporates two essential components:

- *Using native plants that are adapted to Connecticut's climate and that require minimal watering, fertilizer, and pesticide application*
- *Improving soils by adding soil amendments or using mulches to reduce the need for watering by increasing the moisture retained in the soil*

(Salsedo and Crawford, 2000). In addition to promoting water conservation, minimizing water use and water loss will reduce the transport of pollutants into downstream surface waters. Because xeriscaping typically results in a reduced need for pesticides and fertilizers as part of landscape maintenance, this approach to lawn and turf management also reduces nutrient and pesticide contamination in stormwater runoff.

Residential and commercial property owners, as well as municipalities and other government agencies responsible for maintaining large vegetated areas, can use Xeriscaping. Xeriscaping incorporates seven basic principles that are also generally applicable to lawn and turf management:

Planning and Design: Appropriate and thoughtful planning and design is critical for the long-term success of the xeriscaped landscape. Landscape planning should consider soil and topographic characteristics, light conditions, drainage, existing plantings to be preserved, and owner preferences such as the desired level of maintenance, budget constraints and plant and color preferences (NYCDEP, 2002).

Soil Improvements: Improving soil conditions will help to retain water in the soil. Soil should be analyzed to determine current conditions and needed soil amendments. Addition of organic matter such as compost or peat moss to the soil will improve soil moisture retaining capabilities. The soil below the surface layer should be examined to identify limitations such as compaction.

Practical Turf Areas: Because of the water requirements of many turf grasses, limit or reduce the amount of turf areas (EPA, 2002), or convert existing turf areas to the alternatives described below. Groundcovers, planting beds or permeable surfaces like wood decks and brick-on-sand walkways are options for reducing turf areas (Salsedo and Crawford, 2000). Turf areas should be designed in rounded, compact shapes to water and mow more efficiently and appropriate turf varieties should be selected for the site. See the plant list in **Appendix A** for suggestions.

Appropriate Plant Selection: Selecting trees, shrubs, flowers, grasses, and groundcovers that are either native to the region or are non-invasive, non-native adapted species will reduce the amount of watering needed. These plants are adapted to the soil and rainfall conditions in Connecticut and in many cases will require minimal or no watering after an establishment period. Choosing a variety of plants will avoid a monoculture, which may be more susceptible to pest or insect problems than more stable and diverse plant populations (Greenbuilder, 2001). Native plants are also less susceptible to pests or disease (DEP, 1999b). In addition, it is advisable to select plants from reputable nurseries since these plants are often more viable. A partial list of native species is provided in **Appendix A**. For additional information on native species selection and availability, refer to the Additional Information Sources at the end of this chapter.

Efficient Irrigation: Irrigation techniques can be used to reduce overall water use. Encouraging the growth of deep roots enables plants to reach deeper into the soil for moisture. Watering only when needed and allowing the water to penetrate deeper into the soil will encourage deeper root growth (EPA, 2002). A soil moisture sensor can also be used to determine when watering is necessary. Using a soaker hose or drip irrigation system will target watering and result in less evaporation than occurs with sprinkler systems. Watering in the early morning and evening will also reduce evaporation losses. Collection of residential roof runoff in a rain barrel or cistern can provide a reservoir for landscape watering with high quality water (Salsedo and Crawford, 2000). In addition to these irrigation techniques, plants should also be grouped by water needs to reduce overall water usage.

Effective Use of Mulches: Use of mulch helps to maintain soil moisture, reduce weed growth, and prevent erosion (EPA, 2002). Organic mulches such as peat moss, compost, wood chips, shredded bark or bark nuggets, pine needles, cocoa bean shells, leaves, and sawdust retain soil moisture and provide nutrients to the soil for plant growth. Inorganic mulches such as sheeting, stone, or gravel will also reduce moisture loss, but will not provide nutrients and are recommended only for unplanted areas. Mulch typically should be placed in layers three to four inches thick and should be set back a few inches from shrub stems or tree trunks to avoid possible rodent damage to the bark.

Appropriate Regular Maintenance: Properly timed maintenance such as pruning, liming and fertilizing (only when indicated by soil testing), weeding, pest control and mowing will encourage the long-term viability of the xeriscaped landscape (NYCDEP, 2002). A composting area for yard and household waste will provide mulch and reduce solid waste disposal. Alternatively, designation of several smaller planting beds or areas in the landscape where grass clippings, pine needles or leaves can be recycled as mulch can decrease overall maintenance and create conveniently located supplies of organic mulch (Salsedo and Crawford, 2000). Mowing turf areas high and often lowers the stress on grasses and reduces watering needs. By setting mower blades at three inches and mowing when the lawn is at approximately four inches, clippings are less likely to mat and will provide nutrients for the lawn (DFWELE, 2001).

In addition to the xeriscaping concepts described above, no landscaping debris (grass clippings, leaves, brush, prunings, mulch, soil, etc.) should be deposited, dumped, blown, or swept directly into a watercourse, wetland, storm drainage system, or public right of way.

5.4.2 Fertilizer and Pesticide Management

Landscaping and gardening activities can result in contamination of stormwater through fertilizer and pesticide runoff. Over-application or mis-application of fertilizers can be a significant source of nutrients such as phosphorus and nitrogen in stormwater runoff. Pesticides in stormwater runoff may be toxic to aquatic organisms. The selection, rate, and timing of application of both fertilizers and pesticides are key for minimizing possible runoff contamination. These source control measures can be implemented by citizens, businesses, municipalities, and government agencies to minimize stormwater contamination.

Soil testing should be done prior to fertilizer application to ensure that appropriate fertilizers are selected and that the rate of fertilizer application is suitable for the soil conditions. Soil often contains adequate levels of phosphorous, and most fertilizer mixes contain significantly more phosphorous than necessary. Therefore, low-phosphorous fertilizers may be appropriate under most conditions. Phosphorous application is typically most critical when seeding. Slow-release organic fertilizers are recommended, as they are potentially less toxic than other types of commercial fertilizers and are less likely to enter stormwater runoff (EPA, 2002).

Fertilization should be timed so that it is most beneficial to the target species. For example, warm season grasses such as Creeping Red Fescue (Festuca rubra), Big Bluestem (Andropogon gerardii), or Little Bluestem (Schizachyrium scoparius) should be fertilized in small frequent doses in the summer while cool season grasses such as Kentucky bluegrass (Poa pratensis) benefit from fall fertilization (EPA, 2002). Research has shown that there is little or no benefit to applying fertilizers to turf after mid-September in Connecticut since nitrogen is leached into the soil with minimal or no benefit to the vegetation. In addition, to minimize mobilization of fertilizer into surface water runoff, fertilizer should not be applied on a windy day or immediately before a heavy rain.

Pesticides, which include herbicides, insecticides, fungicides, and rodenticides, should only be utilized when absolutely necessary and should be selected to specifically target the pests of concern. Potential pests, which may be weeds, diseases, insects, or rodents, should be positively identified in order to determine if they pose an actual threat to the landscape and to enable the targeted selection of pesticides. If possible, the use of chemical pesticides should be avoided. When chemical pesticide use is unavoidable, the least toxic pesticide that targets the pest of concern should be selected. This approach to pesticide usage is formalized in a management technique called Integrated Pest Management (IPM). IPM developed in the turfgrass management field to produce high quality ornamental turfgrass with the most judicious use of pesticides. The principals of IPM are applicable to any landscape. IPM combines monitoring, pest trapping, establishment of action thresholds, use of resistant varieties and cultivars, cultural, physical, and biological controls, and precise timing and application of pesticide treatments (DEP, 1999b).

As discussed in the section on xeriscaping, native plant species are typically better adapted to the local environment and require less fertilization and are less susceptible to pests and disease.

5.4.3 Animal Waste Management

The fecal matter of domestic pets and waterfowl can be carried by stormwater runoff into nearby waterbodies or storm drainage systems. In addition to contributing solids to stormwater, animal fecal matter is a source of nutrients and pathogens, such as bacteria and viruses, in stormwater runoff (EPA, 2002). Nutrients can contribute to eutrophication of waterbodies, which together with the oxygen consumption caused by decaying fecal matter, can encourage oxygen-depleting conditions in water bodies.

Recommended methods for proper disposal of domestic pet waste include:

- *Bagging the waste and disposing of it in household trash (EPA, 2002)*
- *Burying it in at least 5 inches of soil away from vegetable gardens and water supplies (University of Wisconsin – Extension, 1999)*

Source control and pollution prevention techniques for pet waste management rely on modification of the behavior of pet owners and typically involve the combined use of public education campaigns and local ordinances. Many people are not aware of the potential pollution caused by their pets. Information on both the pollution effects of pet waste and the proper methods for collection and disposal of the waste can be distributed to pet owners through direct mailings or municipal utility/tax bill enclosures, local veterinarians, local pet stores, and as part of a municipal dog or pet licensing process.

Creating an environment that encourages proper pet waste disposal in areas such as public parks where pet waste is likely to be found is an additional method of pollution prevention. Signage requesting that owners pick up and dispose of pet waste as well as the availability of plastic bags, scoops, and disposal receptacles are common techniques used. Local ordinances mandating pet waste removal and disposal are an additional tool. Such "pooper-scooper" laws typically require pet owners to remove and dispose of any waste generated by their pet at a location other than the owner's property and may include fines. In areas of sensitive water resources, such as bathing beaches, public water supplies or shellfish areas, prohibition of domestic pets is an additional source control mechanism.

In addition to domestic pets, waterfowl can be a significant source of nutrient and pathogen loading to surface waters. Canada geese are Connecticut's largest native waterfowl population and, along with gulls, are the primary sources of waterfowl-related water quality impacts. Since the 1950s, the "resident" population of Canada geese has grown dramatically. Unlike migrant populations that travel south in the winter, resident geese are well adapted to suburban habitat and live year-round in areas that provide a combination of open water, cover, and grazing areas. Park ponds, reservoirs, and golf courses are examples of areas that typically provide a combination of these habitat features. (DEP, 1999c).

Lethal methods of waterfowl control, such as hunting, are among the most effective, but are typically not feasible in the suburban and urban areas where waterfowl management is of greatest concern (DEP, 1999c). Other control methods for waterfowl, especially geese, consist of:

Habitat Modification: This method focuses on changes in the vegetation available for grazing and/or the alteration of the relationship between open water and grazing habitat. Geese are especially attracted to ponds and lakes that have gradually sloping banks and lawn or other similar vegetation, allowing them to easily walk between open water and land. Planting unpalatable species such as pachysandra or allowing vegetation to grow tall in areas adjacent to water bodies will make these areas unattractive for grazing. Planting of species that also create a visual and physical barrier (see below) between land and open water will also make the habitat less conducive to geese populations. In addition, it is important that people do not artificially feed geese (i.e., bread or grain), which can be a particularly prevalent problem in public parks.

Barriers and Exclusion: Barriers for goose control should be at least 3-feet high. Effective barriers can consist of either vegetation or structural materials. Dense shrub plantings or mixed-vegetation buffer zones 20 to 100-feet wide along a shoreline are possible vegetative barriers. Wooden snow fence, soft or hard nylon fencing, or chicken wire or weld wire fences are artificial barriers that can be effective, although not aesthetically pleasing, for excluding geese from freely crossing between open water and grazing areas (DEP, 1999c; Metropolitan Council, 2001).

Non-Toxic Repellants: Repellants that either change the reflective property of the grass and make it look unnatural to geese or irritate the throats of the geese can be sprayed on feeding areas.

Frightening Methods: In order to be effective, frightening methods need to be employed before geese establish a feeding pattern at a particular location because they may become accustomed to repetitious frightening methods once they realize that there is no real danger (DEP, 1999c). Typically, frightening methods are most effective when they coincide with feeding times, typically sunrise and sunset. Frightening techniques can consist of pyrotechnics that create loud noises. Visual methods such as helium balloons, flags, and scarecrows are often effective because geese are uncomfortable with moving objects overhead. Mylar plastic flash tape, strung like a string fence at one to two feet above the ground is another visual frightening method. Where feasible, free-ranging dogs trained to chase geese or even tethered dogs that are allowed extensive movement can be effective.

Mute swans are also an increasing problem in natural and constructed ponds/wetlands. These exotic birds are very territorial and chase away native waterfowl. In addition to increased loadings of fecal matter, these birds can damage planted and established vegetation and can uproot submerged plants. Mute swans have been identified as a significant cause of eelgrass bed decline in Long Island Sound.

5.5 Model Stormwater Ordinances

Municipal ordinances provide the legal authority for resource protection on the local level. Although ordinances need to be specific to the particular conditions of a community, stormwater-related ordinances typically contain the following basic elements:

Finding of Fact/Purpose and Objectives: This section addresses why the ordinance is necessary and what its objective and purpose is.

Authority/Jurisdiction: This section describes the authority for the adoption of the ordinance and the jurisdiction covered under the ordinance.

Definitions: Key terms used in the ordinance are clearly defined in this section.

Requirements and Standards: These elements may vary considerably depending upon the topic of the ordinance and the content of other ordinances already in place. These sections describe the actual elements of resource protection.

Enforcement: This section describes violations of the ordinance, notices of violations, and penalties.

Appeals and Variances: These sections describe the mechanism and requirements for appeals and variances under the ordinance.

(Wisconsin Department of Natural Resources, 1994; EPA, 2000). As described in prior sections of this chapter, municipal ordinances provide an enforceable method of instituting the following pollution prevention and source control measures:

Illicit Discharges: An illicit discharge ordinance regulates non-stormwater discharges to municipal stormwater drainage systems. A critical element of illicit discharge ordinances is a guaranteed "right of entry" to private property, giving the authority to inspect properties suspected of releasing contaminated discharges into the stormwater drainage system (CWP, 2002a). **Appendix C** contains a model illicit discharge detection and elimination ordinance developed by DEP in conjunction with the Stormwater Phase II Municipal Separate Storm Sewer System (MS4) General Permit.

Post-Construction Stormwater Controls: Ordinances for post-construction stormwater controls are useful for communities that have no existing ordinances addressing stormwater management. Typically a post-construction stormwater control ordinance will include language referring to the latest version of a stormwater guidance manual so that the ordinance itself will not need to be updated to reflect technological advances or changes in stormwater management techniques. The ordinance should also require a post-construction stormwater management plan, including plan contents and operation and maintenance requirements (CWP, 2002b).

To ensure that new and redevelopment projects include stormwater management plans, municipal planning and zoning commissions should review and revise their site and subdivision plan submission requirements to require such plans. Chapter Nine describes how to develop a site stormwater management plan.

Stormwater Operation and Maintenance: For communities with existing ordinances that address stormwater management, but do not include provisions for post-construction operations and maintenance, a stormwater operation and maintenance ordinance can augment existing local stormwater management ordinances. Like the model ordinance in **Appendix C**, a stormwater operation and maintenance ordinance should specify requirements for an operation and maintenance plan, the entity responsible for long-term maintenance, and the frequency of inspections (CWP, 2002c).

The Center for Watershed Protection (www.cwp.org) and the U.S. Environmental Protection Agency Office of Water (www.epa.gov/nps/ordinance/index.htm) provide information on local stormwater-related ordinances, including model ordinances and examples of local ordinances from communities across the United States.

The model ordinances in **Appendix C** of this Manual are provided for informational purposes only and should not be adopted as a legal requirement without modification to fit the specific needs of the municipality and the local water resource conditions.

5.6 Public Education and Outreach

Nearly all source control and pollution prevention techniques rely on some level and form of public education. In some cases, education efforts must be targeted at municipal officials and public works employees (e.g., stormwater ordinances, roadway deicing application, storm drainage system maintenance). The general public, including business owners and operators, plays an important role in almost all of the source control and pollution prevention measures described in this chapter. Often, the public is not aware of the critical role they have in protecting water resources. Public education is an important part of an overall pollution prevention and source control program because it raises awareness of both personal responsibilities and the responsibilities of others relative to environmental protection, and teaches people what individual actions they can take to prevent pollution. This increased understanding has the additional benefit of fostering support for other stormwater management efforts.

This section describes some common general techniques for public education that can be used in addition to the specific methods described in earlier sections.

Public Education Materials

Public education campaigns can consist of a variety of elements including:

- *Educational displays, pamphlets, booklets, and utility stuffers*
- *Use of the media (newspapers, television, radio)*
- *Promotional giveaways (hats, t-shirts, bumper stickers, etc.)*
- *Stormwater educational materials*
- *Classroom education*

The choice of outreach materials is dependent upon the resources available and the target audience. A variety of general educational materials on stormwater and pollution prevention are available from state and federal government agencies, as well as education and industry groups (see references below for a partial list of such contacts).

Businesses

Because many commercial activities can potentially contribute to stormwater pollution, businesses are a common target for public education. Public outreach activities should be targeted to the specific business audience, i.e., automotive-related, dry cleaners, etc. Materials can include posters, calendars, flyers, brochures, handbooks, and best management practice (BMP) fact sheets targeted to the specific industry. Because of the wide variety of businesses, public education and outreach programs should prioritize efforts on business types that might have the most potential to contribute to stormwater pollution or might be most receptive to outreach.

Municipal Officials

Because of their involvement in establishing and implementing local source control and pollution prevention measures, municipal officials are an important target audience for education related to stormwater management and pollution prevention. The Nonpoint Education for Municipal Officials (NEMO) Project (http://www.nemo.uconn.edu) is an educational program for Connecticut local land use officials that addresses the relationship between land use and natural resource protection. NEMO is a collaboration between three branches of the University of Connecticut: the Cooperative Extension System, the Natural Resources Management and Engineering Department, and the Connecticut Sea Grant College Program. NEMO's educational programs are available to communities free of charge. In addition, the program provides educational publications and in some cases, maps, web-based information, and individual consultation. The materials cover a range of topics from open space planning to site plan review for stormwater management.

In addition to the information and assistance available through NEMO, DEP and other government and non-profit agencies provide a variety of outreach programs and materials focused on educating local decision-makers about stormwater management and pollution prevention.

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Chapter 6

Introduction to Stormwater Treatment Practices

Volume II: Design

Chapter 6

Introduction to Stormwater Treatment Practices

6.1 Introduction

This chapter introduces stormwater treatment practices that are acceptable for water quality treatment in Connecticut, either alone or in combination with source controls and other treatment practices. The following sections describe three categories of stormwater treatment practices:

- *Primary Stormwater Treatment Practices*
- *Secondary Stormwater Treatment Practices*
- *Stormwater Treatment Train*

This chapter also provides general information on maintenance considerations and performance monitoring for stormwater treatment practices.

Stormwater treatment practices are structural controls primarily designed to remove pollutants from stormwater runoff, but they also can provide other benefits including groundwater recharge, peak runoff attenuation, and stream channel protection. As described in Chapter Three of this Manual, stormwater treatment practices are one element of a comprehensive stormwater management strategy, and should be selected and designed only after consideration of effective site planning/design and source controls that can reduce the volume of runoff and the size and cost of stormwater treatment.

6.2 Primary Stormwater Treatment Practices

The stormwater treatment practices listed in this section, referred to as primary stormwater treatment practices, are capable of providing high levels of water quality treatment as stand-alone devices. A growing body of research on stormwater treatment practices throughout the United States, as well as field experience in Connecticut and other northeastern states, has demonstrated that these practices are capable of:

- *Capturing and treating the design water quality volume (WQV) or design water quality flow (WQF) (see Chapter Seven)*
- *Removing at least 80 percent of the average annual total suspended solids (TSS) load*
- *Removing at least 80 percent of floatable debris, including oil and petroleum products, for all flow rates up to the design water quality flow, either alone or in combination with pretreatment*
- *Acceptable performance or operational longevity in the field*

(NYDEC, 2001; MDE, 2000). The above performance standards assume that these stormwater treatment practices are properly selected, sited, designed, constructed, and maintained in accordance with the guidelines contained in this Manual.

The State of Connecticut has adopted the 80 percent TSS removal goal based on EPA guidance and its widespread use as a target stormwater quality performance standard. TSS is considered a suitable target pollutant constituent for a removal standard because of its widespread impact on water quality and aquatic habitat degradation, because many other pollutants including heavy metals, bacteria, and organic chemicals adsorb to sediment particles, and because it has been the most frequently and consistently sampled stormwater constituent (MADEP, 1997).

Primary stormwater treatment practices can be grouped into five major categories:

Stormwater Ponds: Stormwater ponds maintain either a permanent pool of water or a combination of a permanent pool and extended detention. The permanent pool of water in these systems enhances pollutant removal through mechanisms such as sedimentation, biological uptake, microbial breakdown, gas exchange, volatilization, and decomposition. This category of stormwater ponds does not include traditional dry detention ponds or dry flood control basins, which do not provide significant water quality treatment functions (see the Secondary Treatment Practices described in this chapter). Treatment practices in this category include:

- *Wet pond*
- *Micropool extended detention pond*
- *Wet extended detention pond*
- *Multiple pond system*

Stormwater Wetlands: Stormwater wetlands are constructed wetland systems designed to treat polluted stormwater runoff by several mechanisms, including sedimentation, adsorption, biological uptake, photodegradation, and microbial breakdown. Stormwater wetlands typically include sediment forebays, shallow and deep pool areas, meandering flow paths, and vegetative measures to enhance pollutant removal. Stormwater wetlands are engineered specifically for pollutant removal and flood control purposes. They typically do not have the full range of ecological functions of natural wetlands or wetlands constructed for compensatory storage or wetland mitigation. Stormwater wetland practices in this category include:

- *Shallow wetland*
- *Extended detention wetland*
- *Pond/wetland system*

Infiltration Practices: Infiltration practices are designed to capture, temporarily store, and infiltrate stormwater into porous soils. Pollutant removal occurs through adsorption of pollutants onto soil particles, and subsequent biological and chemical conversion in the soil. Infiltration practices aid in recharging groundwater but must be carefully designed and maintained to prevent clogging and system failure. Infiltration practices in this category include:

- *Infiltration trench*
- *Infiltration basin*

Filtering Practices: Filtering practices treat stormwater runoff by capturing, temporarily storing, and filtering stormwater through sand, soil, organic material, or other porous media. As the water flows through the filter media, sediment particles and attached pollutants, as well as some soluble pollutants, are removed through physical straining and adsorption. Pretreatment is generally required to remove debris and floatables, and prolong the life of the filter. Filtering practices in this category include:

- *Surface sand filter*
- *Underground sand filter*
- *Perimeter sand filter*
- *Bioretention*

Water Quality Swales: Water quality swales reduce the velocity of and temporarily store stormwater runoff and promote infiltration. Pollutant removal mechanisms in water quality swales are similar to constructed wetlands and include sedimentation, adsorption, biological uptake, and microbial breakdown. These practices differ from conventional grass channels and ditches that are primarily designed for conveyance, as they provide higher levels of pollutant removal. Practices in this category include:

- *Dry swale*
- *Wet swale*

The above practices generally have the highest removal efficiencies for pollutants such as nutrients and metals, in addition to TSS. Pollutant removal summary data for stormwater treatment practices are included in Chapter Eight.

Other stormwater treatment practices not listed above, such as the secondary treatment practices described in the following section, may be classified as primary practices at the discretion of the local review authority and/or DEP. In order to be considered a primary stormwater treatment practice, a practice must demonstrate the ability to treat the design water quality volume or an equivalent design water quality flow, meet the 80 percent TSS and floatables criteria, and have proven operational longevity. It is conceivable that as treatment systems age, they may lose their effectiveness and may further be considered a pollutant source. The following sections describe criteria for acceptance of new technologies as primary treatment practices.

6.3 Secondary Stormwater Treatment Practices

A number of stormwater treatment practices may not be suitable as stand-alone treatment because they either are not capable of meeting the water quality treatment performance criteria described in the previous section or have not yet received the thorough evaluation needed to demonstrate the capabilities for meeting the performance criteria. These practices, termed secondary stormwater treatment practices, generally fall into either of the following categories:

- *Conventional Practices*
- *Innovative/Emerging Technologies*

Table 6-1 summarizes the rationale for the limited use of these practices for water quality control, as well as applications suitable for their use, such as pretreatment or use in a treatment train to achieve multiple stormwater management objectives and to satisfy the design criteria in Chapter Seven (see Section 6.4 below). Chapter Eleven contains limited design guidance for these secondary practices.

6.3.1 Conventional Practices

Conventional or "public-domain" (as opposed to proprietary) secondary treatment practices are practices that have traditionally been used to provide some water quality benefits, but that do not provide the same level of treatment or broad water quality functions as primary stormwater treatment practices. Consequently, their application is limited to use as pretreatment or supplemental treatment practices in conjunction with primary practices (i.e., a treatment train), or to achieve other objectives such as groundwater recharge, channel protection, and peak runoff attenuation. Conventional secondary treatment practices addressed in this Manual include:

- *Dry Detention Ponds*
- *Underground Detention Facilities*
- *Deep Sump Catch Basins*
- *Conventional Oil/Particle Separators*
- *Dry Wells*
- *Permeable Pavement*
- *Vegetated Filter Strips and Level Spreaders*
- *Grass Drainage Channels*

6.3.2 Innovative/Emerging Technologies

The other category of secondary treatment practices addressed in this Manual includes innovative and emerging technologies, which are typically proprietary systems. Stormwater treatment practices are continually evolving in response to advances in treatment technology, availability and affordability of new technology, and recognition of new treatment needs. These innovative and emerging technologies are those for which preliminary performance data indicate that they may provide a valuable stormwater treatment function. However, unlike the primary stormwater treatment practices described previously in this chapter, these technologies have not been evaluated in sufficient detail to demonstrate proven capabilities for meeting established performance standards, including pollutant removal and field longevity (see **Table 6-1**).

The following section provides examples of recently developed innovative and emerging technologies for stormwater treatment. Chapter Eleven also provides limited design guidance for these technologies. As secondary treatment practices, innovative and emerging technologies are suitable for pretreatment or for use in a treatment train approach. Emerging technologies generally are also good candidates for stormwater retrofits and where land is unavailable for larger systems. Their use as stand-alone treatment devices (i.e., primary treatment practices) should be evaluated using consistent and technically rigorous protocols. This section describes recommended criteria for evaluating new or emerging stormwater treatment technologies. New or emerging technologies that meet these criteria may be acceptable as primary treatment practices.

Examples of Innovative and Emerging Technologies

Most innovative or emerging technologies are proprietary devices developed by various manufacturers and vendors. System designs vary considerably, although most currently available technologies generally can be grouped into one of the following categories:

Catch Basin Inserts: As the name implies, catch basin inserts are placed directly inside of existing catch basins to remove pollutants from stormwater. Stormwater flows into the catch basin and is treated as it passes through the structure. The insert consists of a structure, such as a tray, basket, or bag that typically contains a pollutant removal medium (i.e., filter media) and a method for suspending the structure in the catch basin (Lee, 2001). Although filter media is commonly used, basket-type inserts constructed of wire mesh and fabric bag-type inserts are also used without filter media for removing gross particles (i.e., trash and debris). Although they have the potential to remove total suspended solids, organics, and metals, the removal capabilities depend on the pollutant loading characteristics of the stormwater and the choice of filter medium. Because these devices are limited by the size of the catch basin, there is a relatively short contact time between stormwater and the media for

Table 6-1 Summary of Secondary Stormwater Treatment Practices

Practice	Reasons for Limited Use	Suitable Applications
Conventional Practices		
Dry Detention Ponds	❍ Not intended for water quality treatment. Designed to empty out between storms; lack the permanent pool or extended detention required for adequate stormwater treatment ❍ Settled particulates can be resuspended between storms	❍ Flood control and channel protection
Catch Basins	❍ Limited pollutant removal ❍ No volume control ❍ Resuspension of settled particulates	❍ Pretreatment or in combination with other stormwater treatment practices ❍ Stormwater retrofits
Conventional Oil/ Particle Separators	❍ Limited pollutant removal ❍ No volume control ❍ Resuspension of settled particulates	❍ Pretreatment or in combination with other stormwater treatment practices ❍ Highly impervious areas with substantial vehicle traffic
Underground Detention Facilities	❍ Not intended for water quality treatment ❍ Particulates can be resuspended between storms	❍ Flood control and channel protection ❍ Space-limited or ultra-urban sites
Permeable Pavement	❍ Reduced performance in cold climates due to clogging by road sand and salt ❍ Porous asphalt or concrete recommended for limited use in Connecticut	❍ Modular concrete paving blocks, modular concrete or plastic lattice, or cast-in-place concrete grids are suitable for use in spillover parking, parking aisles, residential driveways, and roadside rights-of-way
Dry Wells	❍ Not intended as stand-alone stormwater runoff quality or quantity control ❍ Potential for clogging/failure ❍ Applicable to small drainage areas ❍ Potential groundwater quality impacts	❍ Infiltration of clean rooftop runoff ❍ Stormwater retrofits ❍ Space-limited ultra-urban ❍ Pretreatment or in combination with other stormwater treatment practices
Vegetated Filter Strips	❍ Typically, cannot alone achieve the 80% TSS removal goal	❍ Pretreatment or in combination with other treatment practices ❍ Limited groundwater recharge ❍ Outer zone of a stream buffer ❍ Residential applications and parking lots
Grass Drainage Channels	❍ Typically, cannot alone achieve the 80% TSS removal goal	❍ Part of runoff conveyance system to provide pretreatment ❍ Replace curb and gutter drainage ❍ Limited groundwater recharge
Level Spreaders	❍ Typically, cannot alone achieve the 80% TSS removal goal	❍ Pretreatment or in combination with other treatment practices ❍ Use with filter strips and at outlets of other treatment practices to distribute flow ❍ Groundwater recharge
Innovative/Emerging Technologies		
Catch Basin Inserts	❍ Limited performance data available ❍ High maintenance and susceptible to clogging	❍ Stormwater retrofits, ultra-urban sites ❍ Small drainage areas without excessive solids loadings ❍ Pretreatment or in combination with other treatment practices
Hydrodynamic Separators	❍ Limited performance data available ❍ Performance varies with flow rate	❍ Pretreatment or in combination with other treatment practices ❍ Stormwater retrofits, ultra-urban sites
Media Filters	❍ Limited performance data available	❍ Pretreatment or in combination with other treatment practices ❍ Stormwater retrofits, ultra-urban sites
Underground Infiltration Systems	❍ Limited performance data available	❍ Groundwater recharge ❍ Stormwater retrofits
Alum Injection	❍ Requires ongoing operation and monitoring ❍ Limited performance data available ❍ Potential for negative impacts to downstream receiving waters	❍ Stormwater retrofits, ultra-urban sites ❍ Pretreatment or in combination with other treatment practices
Advanced Treatment	❍ Requires ongoing operation and monitoring ❍ High cost and level of complexity ❍ Limited performance data available	❍ Only as required, where other primary or secondary practices are insufficient

pollutant removal and little storage area for the material that is removed. Consequently, frequent maintenance is typically required to avoid clogging of the insert and there is the possibility of re-suspension of filtered pollutants (Washington, 2000).

Hydrodynamic Separators: This group of stormwater treatment technologies is designed to remove large particle total suspended solids and large oil droplets. They consist primarily of cylindrical-shaped devices that are designed to fit in or adjacent to existing stormwater drainage systems (Washington, 2000). The most common mechanism used in these devices is vortex-enhanced sedimentation, also called swirl concentration. In these structures, often called swirl concentrators, stormwater enters as tangential inlet flow into the side of the cylindrical structure. As the stormwater spirals through the chamber, the swirling motion causes the sediments to settle by gravity, removing them from the stormwater (EPA, 2002). Some devices also have compartments or chambers to trap oil and other floatables.

Although swirl concentration is the technology employed by most hydrodynamic separators, some systems use circular screening systems or engineered cylindrical sedimentation. Circular screened systems use a combination of screens, baffles, and inlet and outlet structures to remove debris, large particle total suspended solids, and large oil droplets. Structures using engineered cylindrical sedimentation use an arrangement of internal baffles and an oil and sediment storage compartment. Other proprietary technologies incorporate an internal high flow bypass with a baffle system in a rectangular structure to simulate plug flow operation. When properly engineered and tested, these systems can also be an improvement over conventional oil/particle separators and offer removal efficiencies similar to swirl chamber technologies. Absorbent materials can also be added to these structures to increase removal efficiency of oil and hydrocarbons (Washington, 2000).

Media Filters: In this type of treatment practice, media is placed within filter cartridges that are typically enclosed in concrete vaults. Stormwater is passed through the media, which traps particulates and/or soluble pollutants. Various materials can be used as filter media including pleated fabric, activated charcoal, perlite, amended sand and perlite mixes, and zeolite. Selection of filter media is a function of the pollutants targeted for removal. Pretreatment prior to the filter media is typically necessary for stormwater with high total suspended solids, hydrocarbon, and debris loadings that may cause clogging and premature filter failure (Washington, 2000).

Underground Infiltration Systems: Various types of underground infiltration structures, such as pre-manufactured pipes, vaults, and modular structures, have been developed as alternatives to infiltration trenches and basins for space-limited sites and stormwater retrofit applications. Similar to traditional infiltration trenches and basins, these systems are designed to capture, temporarily store, and infiltrate the design water quality volume over several days. Performance of underground infiltration structures varies by manufacturer and system design. These systems are currently considered secondary treatment practices due to limited field performance data, although pollutant removal efficiency is anticipated to be similar to that of infiltration trenches and basins.

Advanced Treatment: The pollutant removal techniques utilized in drinking water treatment processes are potential advanced treatment options for stormwater (Lee, 2001). Alum has been used extensively as a coagulant in pond and lake management applications. Alum injection has also been used more recently in stormwater applications for reducing concentrations of fine sediment and phosphorus in stormwater discharges to eutrophic water bodies. Water-soluble anionic polyacrylamide (PAM) has also been used as a coagulant in drinking water treatment and pond dredging operations to enhance settling of solids. PAM has also been land applied as an erosion and sedimentation control measure. Recently, the use of PAM in pre-formed shapes such as logs in ditches or open swales has been introduced to enhance removal of fine sediment in stormwater runoff. However, the practicability of methods such as ion exchange, reverse osmosis, disinfection, and ultrafiltration is undocumented for stormwater treatment. The success of these methods in drinking water treatment suggests that they may have potential applications in areas where conventional stormwater treatment methods are unable to meet stringent stormwater quality standards or established waste load allocations. However, these technologies are beyond the scope of this Manual.

Criteria for Evaluating New Practices

New and emerging stormwater treatment practices may be acceptable as primary treatment practices if they demonstrate the ability to achieve treatment results consistent with the primary treatment practices described at the beginning of this chapter, specifically:

- *Capture and treatment of the design water quality volume (WQV) or design water quality flow (WQF)*

- *Removal of at least 80 percent of the average annual total suspended solids (TSS) load*
- *Removing at least 80 percent of floatable debris, including oil and petroleum products, for all flow rates up to the design water quality flow (WQF), either alone or in combination with pretreatment*
- *Acceptable performance or operational longevity in the field*
- *Automatic operation during runoff events (i.e., no need for manual activation)*

These capabilities must be demonstrated through field and laboratory testing. Independent validation of data that support specific treatment technology performance claims is recommended. Field performance data should come from field studies conducted under a variety of conditions (e.g., flow rates, contaminant loadings, antecedent moisture conditions, rainfall distribution, land use, percent imperviousness, maintenance intervals) (TARP, 2001). Ideally, the field studies should be conducted over a one-year demonstration period, including cold weather and winter conditions, to capture possible seasonal variations in performance and performance variations as a function of rainfall intensity.

Field data is valuable for verifying performance under actual field conditions. However, the variability of site conditions leads to site-specific performance validation that may be difficult to develop into sizing methodologies. It is recommended that laboratory testing be conducted to establish performance curves for technologies over the full operating range of the system. Performance curves based on laboratory data for various technologies, developed using the same test criteria, applied to the same rainfall and TSS removal model, enable direct comparison between technologies. Laboratory testing must be conducted in accordance with an established protocol for known particle sizes in known concentrations. The Maine Department of Environmental Protection has established one such protocol for comparing innovative technologies.

Performance claim data sets should be collected under a Quality Assurance Project Plan (QAPP) to ensure that the data sets meet data quality objectives and are defensible, and should include flow rates, residence times, and rainfall intensity data with which to interpret these claims. USEPA provides guidance on the development and minimum requirements for a QAPP. (See USEPA references at the end of this chapter.) Standardized test methods and procedures must be used in the collection of data. For example, ASTM methods for flow measurement methods, ASCE hydraulic flow estimation methods, and EPA test methods for water quality analysis are typical standardized test methods. (See TARP (2001)) for a listing of standardized methods for flow and water constituent analysis).

It is recommended that stormwater quality data be collected in accordance with guidance outlined in the Technology Acceptance and Reciprocity Partnership (TARP) Stormwater BMP Demonstration Protocol (2001). The TARP Stormwater BMP Demonstration Protocol has been endorsed by the states of Massachusetts, New York, New Jersey, Illinois, California, Maryland, Pennsylvania, Texas and Virginia to provide a uniform method for demonstrating stormwater technologies and developing test quality assurance plans for certification or verification of performance claims. Treatment efficiencies should be calculated using methods outlined in the joint EPA and ASCE technical memorandum *Determining Urban Stormwater Best Management Practice (BMP) Removal Efficiencies* (URS Greiner Woodward Clyde et al., 1999). In addition, to demonstrate that the performance claims are reliable, significant, and within confidence limits, statistical evaluation of the data must be performed and made available. Performance claims should be given with appropriate confidence intervals (i.e., removal rate of 85% ± 5% at a 95% confidence interval). The EPA Data Quality Assessment Guidance Manual (EPA, 1998) provides information on statistical methods for comparison and validation of data sets.

In addition to performance claims and validation, the following specifications for the treatment technology should be provided:

- *Description of the underlying scientific and engineering principles*
- *Standard drawings, including a process flow diagram*
- *Minimum siting and design specifications necessary to achieve the stated performance*
- *The full range of operating conditions for the technology, including minimum, maximum, and optimal conditions to meet the stated performance claims (flow rate, residence time, rainfall intensity, etc.)*
- *Minimum maintenance requirements to sustain the stated performance*
- *Description of hydraulics and system sizing to meet the performance claims*
- *Discussion of any pretreatment required to meet the stated performance claims*

- *Identification of any special licensing or hauling requirements, safety issues or access requirements associated with installation and/or operation and maintenance*
- *Discussion of the generation, handling, removal and disposal of any discharges, emissions, or other waste byproducts of the treatment technology*

(TARP, 2001). Evaluation protocols and methods similar to those of the TARP Stormwater BMP Demonstration Protocol have also been developed through EPA's Environmental Technology Verification (ETV) program. With funding from the ETV program, the Civil Engineering Research Foundation established the Environmental Technology Evaluation Center (EvTEC), an independent, non-profit verification center that evaluates environmental technologies. EvTEC is collaborating with the Washington State Department of Transportation to verify performance of innovative stormwater treatment practices under field operating conditions. These evaluations are expected to provide comparable, peer-reviewed performance data on these systems (CERF, 2002).

EPA and NSF International, an independent, non-profit testing organization, have developed a testing protocol under the ETV program to determine the viability of runoff treatment technologies and other wet weather flow controls, including urban runoff, combined sewer overflows (CSO), and sanitary sewer overflows (SSO). Participants in the study include vendors who want to demonstrate the effectiveness of their technologies. Results of the pilot will be useful to a variety of stakeholders including municipalities, businesses, vendors, consulting engineers, and regulatory agencies. Once verification reports have been completed, vendors may use the results in their marketing efforts. Results will be made publicly available through EPA's and NSF's Web sites at http://www.epa.gov/etv and http://www.nsf.org/etv, respectively.

6.4 Stormwater Treatment Train

Stormwater treatment practices can be combined in series to enhance pollutant removal or achieve multiple stormwater objectives. The use of a series of treatment practices, as well as site planning techniques and source controls, is referred to as "stormwater treatment trains". The use of a treatment train approach can:

- *Increase the level and reliability of pollutant removal*
- *Accomplish multiple stormwater management objectives (pollutant removal, groundwater recharge, channel protection, peak runoff attenuation, etc.)*
- *Increase the lifespan of treatment devices by distributing pollutant removal over multiple practices or controls*
- *Reduce the potential for resuspension of sediment by reducing flow velocities and increasing flow paths*
- *Allow the use of a wider array of treatment practices, including supplemental practices for pretreatment*

A treatment train may consist of the following types of practices in series to satisfy the design criteria in Chapter Seven:

- *Multiple primary treatment practices*
- *A combination of primary and secondary treatment practices*
- *Multiple secondary treatment practices (at the discretion of the review authority)*

The use of multiple stormwater treatment practices increases the maintenance required to preserve the overall effectiveness of the system. In general, the least expensive and most easily maintained components should be placed at the most upstream point in the treatment train to reduce the maintenance requirements of the downstream components (Metropolitan Council, 2001). The individual treatment practice descriptions in Chapter Eleven include guidance on routine and non-routine maintenance.

6.5 Maintenance

Stormwater treatment practices require regular maintenance to perform successfully. Failure to perform adequate maintenance can lead to reductions in pollutant removal efficiency or actually increase pollutant loadings and aggravate downstream impacts. Stormwater treatment practices should be routinely inspected and maintained following construction to ensure that the controls are in proper working condition and operating as designed. General maintenance guidelines for stormwater treatment practices are summarized below. Chapter Eleven contains recommended maintenance for specific stormwater treatment practices. **Appendix E** contains maintenance inspection checklists for specific stormwater treatment practices. Additional information on maintenance of stormwater treatment practices can be found in the documents listed at the end of this chapter.

General maintenance requirements for stormwater treatment practices include:

Inspections: Inspections should be performed at regular intervals to ensure proper operation of stormwater treatment practices. Inspections should be conducted at least annually, with additional inspections following large storms. Inspections should include a comprehensive visual check for evidence of the following (not all items apply to every treatment practice):

- *Accumulation of sediment or debris at inlet and outlet structures*
- *Erosion, settlement, or slope failure*
- *Clogging or buildup of fines on infiltration surfaces*
- *Vegetative stress and appropriate water levels for emergent vegetation*
- *Algae growth, stagnant pools, or noxious odors*
- *Deterioration of pipes or conduits*
- *Seepage at the toe of ponds or wetlands*
- *Deterioration or sedimentation in downstream channels and energy dissipators*
- *Evidence of vandalism*
- *Evidence of structural damage by beavers, muskrats, and other wildlife*

Routine Maintenance: Routine maintenance should be performed on a regular basis to maintain proper operation and aesthetics. Routine maintenance should include:

- *Debris and litter removal*
- *Silt and sediment removal*
- *Terrestrial vegetation maintenance*
- *Aquatic vegetation maintenance*
- *Maintenance of mechanical components (valves, gates, access hatches, locks)*

Non-routine Maintenance: Non-routine maintenance refers to corrective measures taken to repair or rehabilitate stormwater controls to proper working condition. Non-routine maintenance is performed as needed, typically in response to problems detected during routine maintenance and inspections, and can include:

- *Erosion and structural repair*
- *Sediment removal and disposal*
- *Nuisance control (odors, mosquitoes, weeds, excessive litter)*

Stormwater treatment practice operation and maintenance requirements are an integral part of a site stormwater management plan (see Chapter Nine). These requirements should include, at a minimum, detailed inspection and maintenance tasks, schedules, responsible parties, and financing provisions. The owner typically maintains stormwater treatment practices at commercial, industrial, and rental residential developments. These facilities generally have staff dedicated to maintenance activities or contract for such services. Maintenance of non-rental residential installations is typically performed by private landowners or property/homeowners associations, which in many cases do not have the technical expertise, resources, or funds to inspect and maintain their stormwater systems. In some cases, local government may accept responsibility for inspecting and maintaining stormwater treatment practices. Local governments should require legally binding maintenance agreements for stormwater treatment practices to clearly delineate maintenance responsibilities. Potential funding mechanisms include general tax revenues, stormwater utility fees, inspection or permit fees, and dedicated funds from land developers. Public education is critical for the success of any stormwater financing program.

Many municipalities consider stormwater treatment practices such as ponds, wetlands, and other "wet" treatment systems as regulated wetland areas, and therefore subject to local inland wetlands and watercourses regulations. Sediment removal and other common maintenance activities may require approval from the local Inland Wetlands and Watercourses Commission, which presents a potential regulatory hurdle to consistent maintenance. To facilitate this approval process, municipalities could issue up to a five-year maintenance permit in conjunction with the primary Inland Wetlands and Watercourses permit for the development or redevelopment project. The permit holder would be responsible for renewing or requesting reissuance of the maintenance permit at five-year intervals. Municipalities should identify all such stormwater management facilities for which they are responsible and issue a five-year renewable maintenance permit. This type of an approach is analogous to DEP's renewable five-year maintenance permits issued to DOT and other state-regulated entities for statewide drainage maintenance activities.

6.6 Performance Monitoring

Currently, there are very limited performance data for stormwater treatment practices in the State of Connecticut. Performance data from the majority of previous monitoring studies conducted throughout the United States are limited by differences in design, performance goals, site parameters, storm events, flow and pollutant loadings, seasonal variations, monitoring methods, efficiency calculation methods or simply by the lack of or inadequacy of information. Several major initiatives are underway nationally to provide a more useful set of data on the effectiveness of individual stormwater treatment practices, and to better understand the relationship between treatment practice design and performance. These include:

- *The Center for Watershed Protection's* National Pollutant Removal Performance Database *(Winer, 2000)*
- *The American Society of Civil Engineers (ASCE)* National Stormwater Best Management Practices (BMP) Database *(Urban Water Resources Research Council of ASCE and Wright Water Engineers, Inc., 2001)*
- *Water Environment Research Foundation (WERF)* Critical Assessment of Stormwater Control (BMP) Selection Issues *(WERF, in progress)*

These databases contain the results of performance studies for individual stormwater treatment practices throughout the United States. While they provide a starting point for pollutant removal estimates, the usefulness of the data is still extremely limited for many of the reasons stated above. The reliability of the data will continue to increase as the results from additional studies are added.

Very few performance monitoring studies have been performed in Connecticut or elsewhere in New England. Performance monitoring is recommended for new and existing stormwater treatment practices in Connecticut to develop a representative and reliable performance database that is specific to the State of Connecticut. Performance monitoring is designed to provide information on the following issues:

- *What degree of pollution control does the treatment practice provide under typical operating conditions?*
- *How does efficiency vary from pollutant to pollutant?*
- *How does efficiency vary with various input concentrations?*
- *How does efficiency vary with storm characteristics such as rainfall amount, rainfall density, antecedent weather conditions?*
- *How do design variables affect performance?*
- *How does efficiency vary with different operational and/or maintenance approaches?*
- *Does efficiency improve, decay, or remain the stable over time?*
- *How does the system's efficiency, performance, and effectiveness compare relative to other stormwater treatment practices?*
- *Does the treatment practice reduce toxicity to acceptable levels?*
- *Does the treatment practice cause an improvement or protect in downstream biotic communities?*
- *Does the treatment practice have potential downstream negative impacts?*

(URS Greiner Woodward Clyde et al., 1999). Standardized test methods and procedures should be used for stormwater performance monitoring studies. Performance monitoring should be consistent with the methods and protocols described previously in this chapter for evaluating new stormwater treatment technologies and the guidance documents referenced therein.

Additional Information Sources

Technology Acceptance and Reciprocity Partnership (TARP), Pennsylvania Department of Environmental Protection,
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Chapter 7
Hydrologic Sizing Criteria for Stormwater Treatment Practices

Volume II: Design

Chapter 7

Hydrologic Sizing Criteria for Stormwater Treatment Practices

7.1 Introduction

This chapter presents a recommended approach for sizing stormwater treatment practices in the State of Connecticut. Although the primary focus of this Manual is on stormwater quality, the management of stormwater quantity is an important related concern. Therefore, the sizing criteria in this chapter are designed to achieve both water quality and quantity control objectives. The recommended sizing criteria have been adapted from the Center for Watershed Protection's Unified Sizing Criteria, which is one of the more comprehensive approaches for sizing stormwater treatment practices developed to date. This approach has been implemented in several other states including Maryland, New York, Vermont, and Georgia.

The sizing approach described in this chapter is intended to manage the full spectrum of storm flows and their associated water quality and quantity impacts. These range from small, frequent storms that are responsible for a majority of the annual runoff volume and pollutant loads to large, infrequent events which are responsible for nuisance and catastrophic flooding. Stormwater treatment practices should be designed to accomplish the following primary objectives:

- *Pollutant reduction*
- *Runoff volume reduction and groundwater recharge*
- *Stream channel protection and peak flow control*

The following sections of this chapter describe criteria and methods for sizing stormwater treatment practices to meet these objectives. These criteria are intended to be consistent with local subdivision and planning/zoning ordinances of most municipalities throughout the state, particularly regarding peak flow control requirements. Some differences may exist between the criteria presented in this chapter and local requirements. Local requirements should be consulted in addition to these criteria. However, the criteria presented in this chapter are recommended where local regulations are less stringent.

7.2 Criteria Applicability

The design criteria presented in this chapter are generally applicable to the following types of new development and redevelopment projects, including phased developments:

- *Any development resulting in the disturbance of greater than or equal to one acre of land*
- *Residential development consisting of 5 or more dwelling units*
- *Residential development consisting of fewer than 5 dwelling units involving construction of a new road or reconstruction of an existing road*
- *Residential development consisting of fewer than 5 dwelling units where imperviousness of the site after construction exceeds 30 percent*
- *Stormwater discharge to wetlands/watercourses*
- *New stormwater discharges located less than 500 feet from tidal wetlands*
- *Land uses or activities with potential for higher pollutant loadings (see **Table 7-5**), excluding the groundwater recharge criterion*
- *Industrial and commercial development projects which result in 10,000 sq. ft. or greater of impervious surface*
- *New highway, road, and street construction*
- *Modifications to existing storm drainage systems*

These and other types of projects not listed above, such as single family residential development, are encouraged to incorporate alternative site design, low impact development practices, and source controls to reduce imperviousness, runoff volumes, and stormwater pollutant sources.

Table 7-1 Summary of Stormwater Treatment Practice Sizing Criteria

Sizing Criteria	Description	Post-Development Storm Magnitude
Pollutant Reduction	***Water Quality Volume (WQV)*** Volume of runoff generated by one inch of rainfall on the site WQV = (1")(R)(A)/12 WQV = water quality volume (ac-ft) R = volumetric runoff coefficient = 0.05+0.009(I) I = percent impervious cover A = site area in acres	First one inch of rainfall
	Water Quality Flow (WQF) Peak flow associated with the water quality volume calculated using the NRCS Graphical Peak Discharge Method	
Groundwater Recharge and Runoff Volume Reduction	***Groundwater Recharge Volume (GRV)*** Maintain pre-development annual groundwater recharge volume to the maximum extent practicable through the use of infiltration measures	Not applicable
	Runoff Capture Volume (RCV) Retain on-site the volume of runoff generated by one inch of rainfall for new stormwater discharges located within 500 feet of tidal wetlands RCV = (1")(R)(A)/12 RCV = runoff capture volume (ac-ft) R = volumetric runoff coefficient = 0.05+0.009(I) A = site area in acres	First one inch of rainfall
Peak Flow Control	***Stream Channel Protection*** Control the 2-yr, 24-hour post-development peak flow rate to 50 percent of the 2-yr, 24-hr pre-development level or to the 1-yr, 24-hr pre-development level ("Two-Year Over-Control").	2-year, 24-hour rainfall
	Conveyance Protection Design the conveyance system leading to, from, and through stormwater management facilities based on the 10-year, 24-hour storm.	10-year, 24-hour rainfall
	Peak Runoff Attenuation Control the post-development peak discharge rates from the 10-, 25-, and 100-year storms to the corresponding pre-development peak discharge rates, as required by the local review authority.	10-, 25-, and 100-year 24-hour rainfall
	Emergency Outlet Sizing Size the emergency outlet to safely pass the post-development peak runoff from, at a minimum, the 100-year storm in a controlled manner without eroding the outlet works and downstream drainages.	100-year, 24-hour rainfall

Consult local regulations for additional criteria. The above criteria are recommended where local regulations are less stringent.

Some of the sizing criteria presented in this chapter may not be practical to meet due to space limitations, soil conditions, and other site constraints which are common in redevelopment or retrofit applications. Treatment practices sized for smaller treatment volumes/flows or exemptions from certain criteria may be appropriate in these situations, at the discretion of the review authority. Conditions where the recommended sizing criteria may not be applicable are identified in the following sections.

7.3 Criteria Summary

Table 7-1 summarizes the hydrologic sizing criteria for stormwater treatment practices in Connecticut. As indicated in **Table 7-1**, the sizing criteria are based on stormwater runoff generated by 24-hour duration storms of various return frequencies (i.e., design storms). **Table 7-2** lists 24-hour design rainfall depths for each county in Connecticut. The rationale for and application of these criteria are described in the following sections.

Table 7-2
Design Rainfall Amounts By County

	24-Hour Rainfall Amount (inches)				
County	1-yr	2-yr	10-yr	25-yr	100-yr
Fairfield	2.7	3.3	5.0	5.7	7.2
Hartford	2.6	3.2	4.7	5.5	6.9
Litchfield	2.6	3.2	4.7	5.5	7.0
Middlesex	2.7	3.3	5.0	5.6	7.1
New Haven	2.7	3.3	5.0	5.6	7.1
New London	2.7	3.4	5.0	5.7	7.1
Tolland	2.6	3.2	4.8	5.5	6.9
Windham	2.6	3.2	4.8	5.5	6.9

Source: TP-40, Department of Commerce, Weather Bureau, May 1961; NWS Hydro-35, Department of Commerce, National Weather Service, June 1977.

7.4 Pollutant Reduction

The pollutant reduction criterion is designed to improve the water quality of stormwater discharges by treating a prescribed water quality volume or associated peak flow, referred to as the water quality flow. Most treatment practices described in this Manual use a volume-based sizing criterion. The exceptions are grass drainage channels, proprietary stormwater treatment devices, and flow diversion structures, where a peak flow rate is utilized.

7.4.1 Water Quality Volume (WQV)

Description

The water quality volume (WQV) is the amount of stormwater runoff from any given storm that should be captured and treated in order to remove a majority of stormwater pollutants on an average annual basis. The recommended WQV, which results in the capture and treatment of the entire runoff volume for 90 percent of the average annual storm events, is equivalent to the runoff associated with the first one-inch of rainfall. The WQV is calculated using the following equation:

$$WQV = \frac{(1'')(R)(A)}{12}$$

where:
- WQV = water quality volume (ac-ft)
- R = volumetric runoff coefficient = 0.05+0.009(I)
- I = percent impervious cover
- A = site area in acres

- *The volumetric runoff coefficient R can also be determined from commonly available tabulated values for various land use, vegetative cover, soil, and ground slope conditions. However, the use of the above equation is recommended since it is directly related to the amount of impervious cover at a site, thereby providing incentive to reduce site imperviousness and the required runoff treatment volume. Reducing impervious cover using the site planning and design techniques described in Chapter Four can significantly reduce the WQV.*
- *Impervious cover should be measured from the site plan and includes all impermeable surfaces that are directly connected to the stormwater treatment practice such as paved and gravel roads, rooftops, driveways, parking lots, sidewalks, pools, patios and decks. In the absence of site-specific information or for large residential developments, impervious cover may be estimated based on average impervious coverage values for various parcel sizes listed in **Table 7-3**. The values shown in **Table 7-3** were derived from research by the University of Connecticut, Cooperative Extension System NEMO Project (Prisloe et al.,).*
- *The WQV should be treated by an acceptable stormwater treatment practice or group of practices described in this Manual. The WQV should be used for the design of the stormwater treatment practices described in this Manual, except grass drainage channels and proprietary stormwater treatment devices (e.g., hydrodynamic separators, catch basin inserts, and media filters), which should be designed based on the water quality flow (WQF).*

Table 7-3 Residential Land Use Impervious Cover	
Parcel Size (acres)	**Average Percent Impervious Cover**
<1/8	39
1/8 to 1/4	28
1/4 to 1/2	21
1/2 to 3/4	16
3/4 to 1	14
1 to 11/2	10
11/2 to 2	9
>2	8

Rationale

The above approach is similar to water quality sizing criteria that have been adopted elsewhere in the United States for the design of stormwater treatment practices. These criteria are intended to remove the majority of pollutants in stormwater runoff at a reasonable cost by capturing and treating runoff from small, frequent storm events that account for a majority of the annual pollutant load, while bypassing larger, infrequent storm events that account for a small percentage of the annual pollutant load. This approach is based on the "first flush" concept, which assumes that the majority of pollutants in urban stormwater runoff are contained in the first half-inch to one-inch of runoff primarily due to pollutant wash-off during the first portion of a storm event. Early studies in Florida determined that the first flush generally carries 90 percent of the pollution from a storm (Novotny, 1995). As a result, treatment of the first half-inch of runoff was adopted as a water quality volume sizing criterion requirement throughout much of the United States. More recent research has shown that pollutant removal achieved using the half-inch rule drops off considerably as site imperviousness increases.

A number of alternative water quality sizing methods were developed to achieve higher pollutant removals for a wider range of site imperviousness. One of the more common methods is known as the "90 Percent Rule", in which the water quality volume is equal to the storage required to capture and treat 90 percent of the annual runoff events (approximately 90 percent of the annual runoff pollutant load) based on analysis of historical precipitation records. The specific rainfall event captured is the storm event that is less than or equal to 90 percent of all 24-hour storms on an average annual basis. In the northeastern U.S., the 90 percent rainfall event is equal to approximately one inch, which is consistent with the recommended WQV sizing criteria for Connecticut.

7.4.2 Water Quality Flow (WQF)

Description

The water quality flow (WQF) is the peak flow rate associated with the water quality design storm or WQV. Although most of the stormwater treatment practices in this Manual should be sized based on WQV, some treatment practices such as grass drainage channels and proprietary treatment devices (designed to treat higher flow rates, thereby requiring less water quality storage volume) are more appropriately designed based on peak flow rate. In this approach, a stormwater treatment facility must have a flow rate capacity equal to or greater than the WQF in order to treat the entire water quality volume (Adams, 1998). In addition, flow diversion structures for off-line stormwater treatment practices can also be designed to bypass flows greater than the WQF.

The WQF should be calculated using the WQV described above and the NRCS, TR-55 Graphical Peak Discharge Method. The procedure is based on the approach described in Claytor and Schueler, 1996 and is summarized in **Appendix B**. Design guidance for flow diversion structures is also found in **Appendix B**.

Rationale

The use of the NRCS, TR-55 Graphical Peak Discharge Method in conjunction with the water quality volume for computing the peak flow associated with the water quality design storm is preferable to both traditional SCS Methods and the Rational Equation, both of which have been widely used for peak runoff calculations and drainage design. The traditional SCS TR-55 methods are valuable for estimating peak discharge rates for large storms (i.e., greater than 2 inches), but can significantly underestimate runoff from small storm events (Claytor and Schueler, 1996). Similarly, the Rational Equation may be appropriate for estimating peak flows for small urbanized drainage areas with short times of concentration, but does not estimate runoff volume and is based on many restrictive assumptions regarding the intensity, duration, and aerial coverage of precipitation. The Rational Equation is highly sensitive to the time of concentration and rainfall intensity, and therefore should only be used with reliable intensity, duration, frequency (IDF) tables or curves for the storm and region of interest (Claytor and Schueler, 1996).

7.5 Groundwater Recharge and Runoff Volume Reduction

This criterion is designed to reduce stormwater runoff volumes and maintain groundwater recharge rates to pre-development levels. The criterion includes two components: groundwater recharge and runoff capture, which are described below.

7.5.1 Groundwater Recharge Volume (GRV)

Description

The groundwater recharge criterion is intended to maintain pre-development annual groundwater recharge volumes by capturing and infiltrating stormwater runoff. The objective of the groundwater recharge criterion is to maintain water table levels, stream baseflow, and wetland moisture levels. Maintaining pre-development groundwater recharge conditions can also reduce the volume requirements dictated by the other sizing criteria (i.e., water quality, channel protection, and peak flow control) and the overall size and cost of stormwater treatment practices.

The groundwater recharge volume (GRV) is the post-development design recharge volume (i.e., on a storm event basis) required to minimize the loss of annual pre-development groundwater recharge. The GRV is determined as a function of annual pre-development recharge for site-specific soils or surficial materials, average annual rainfall volume, and amount of impervious cover on a site. Several approaches can be used to calculate the GRV:

- ***Hydrologic Soil Group Approach:*** *This method was first developed and adopted by the state of Massachusetts, and has since been implemented in several other states including Maryland and Vermont. This approach involves determining the average annual pre-development recharge volume at a site based on the existing site hydrologic soil groups (HSG) as defined by the United States Natural Resources Conservation Service (NRCS) County Soil Surveys (MADEP, 1997). Based on this approach, the GRV can be calculated as the depth of runoff to be recharged, multiplied by the area of impervious cover, as shown below:*

$$GRV = \frac{(D)(A)(I)}{12}$$

where:
GRV = groundwater recharge volume (ac-ft)
D = depth of runoff to be recharged (inches), see **Table 7-4**
A = site area (acres)
I = post-development site imperviousness (decimal, not percent) for new development projects or the net increase in site imperviousness for re-development projects

Table 7-4
Groundwater Recharge Depth

NRCS Hydrologic Soil Group	Average Annual Recharge	Groundwater Recharge Depth (D)
A	18 inches/year	0.4 inches
B	12 inches/year	0.25 inches
C	6 inches/year	0.10 inches
D	3 inches/year	0 inches (waived)

Source: MADEP, 1997.
NRCS – Natural Resources Conservation Service

Where more than one hydrologic soil group is present on a site, a composite or weighted recharge value should be calculated based upon the relative area of each soil group. The GRV should be infiltrated in the most permeable soil group available on the site.

- ***USGS Surficial Materials Approach:*** *This approach is similar to the above hydrologic soil group method, except the pre-development average annual recharge quantities and recharge depths are based on the predominant surficial materials classifications on the site (coarse-grained stratified drift versus glacial till and bedrock) as determined from U.S. Geological Survey (USGS) mapping. In areas underlain by coarse-grained stratified drift, average annual recharge is approximately three times greater than from till and bedrock areas. Areas of coarse-grained stratified drift and till/bedrock can be obtained from USGS 7.5-minute topographic maps of 1:24,000 scale, available from the USGS and DEP. Estimates of average annual recharge values for these materials are available from the Connecticut Water Resources Inventory Bulletins prepared jointly by the USGS and DEP for the major drainage basins throughout the state.*

- ***Other Methods:*** *Pre-development recharge values and the required GRV can also be determined using the results of on-site soil evaluations or other geologic information provided that information sources and methods are clearly documented.*

Meeting the recharge requirement can be accomplished through the use of primary treatment practices (infiltration, bioretention, filtration, and swales), secondary treatment practices (drywells, permeable pavement, level spreaders), and non-structural site design techniques such as disconnection of rooftop runoff and grading. Stormwater ponds, wetlands, and sediment forebays generally are not suitable for groundwater recharge since they are either designed with impermeable bottoms or have significantly reduced permeability due to accumulation of fine sediment. When designing infiltration practices, a factor of safety should be used to account for potential compaction of soils by construction equipment, which can significantly reduce soil infiltration capacity and groundwater recharge. See the design sections of this Manual for guidance on the design and construction of infiltration practices to reduce this potential.

The GRV is considered as part of the total water quality volume (WQV) and therefore can be subtracted from the WQV, provided that the proposed infiltration measures are capable of infiltrating the required recharge volume. Reducing the WQV (and consequently the size and cost of stormwater treatment) is an additional incentive for meeting the groundwater recharge criterion. Additionally, both WQV and GRV are a function of site imperviousness, providing further incentive to minimize site impervious cover.

There are several instances where the groundwater recharge criterion should be waived to protect against contamination of drinking water supplies and mobilization of existing subsurface contamination. Infiltration of stormwater is not recommended under the following site conditions:

- ***Land Uses or Activities with Potential for Higher Pollutant Loads:*** *Infiltration of stormwater from these land uses or activities (**Table 7-5**), also referred to as stormwater "hotspots," can contaminate public and private groundwater supplies. Infiltration of stormwater from these land uses or activities may be allowed by the review authority with appropriate pretreatment. Pretreatment could consist of one or a combination of the primary or secondary treatment practices described in this Manual provided that the treatment practice is designed to remove the stormwater contaminants of concern.*

- ***Subsurface Contamination:*** *Infiltration of stormwater in areas with soil or groundwater contamination such as brownfield sites and urban redevelopment areas can mobilize contaminants.*

- ***Groundwater Supply Areas:*** *Infiltration of stormwater can potentially contaminate groundwater drinking water supplies in public drinking water aquifer recharge areas and wellhead protection areas.*

Rationale

The objective of the groundwater recharge criterion is to mimic the average annual recharge rate for predevelopment site conditions. The recommended approach for calculating the GRV (i.e., the required stormwater infiltration volume) is a function of postdevelopment site imperviousness and the prevailing surface permeability and infiltration capacity. The hydrologic soil group approach uses the widely available NRCS Soil Survey maps and estimates of average annual infiltration rates for each hydrologic soil group. This method has been adopted in Massachusetts and other northeastern states, which have humid climates and receive approximately 44 inches of average annual rainfall. The recharge factors developed for this approach are also valid for Connecticut, which has similar rainfall, soils, and climate.

The alternative surficial materials approach may be less accurate than other soil-specific methods for estimating site-specific infiltration rates. The annual recharge values for surficial material categories are based on basin-wide analyses of stratified drift and till, which may not be applicable to specific sites. However, the approach is believed to be suitable for estimating the required recharge volume and utilizes readily available, published information from the USGS and DEP.

7.5.2 Runoff Capture Volume (RCV)

Description

The objective of the runoff capture criterion is to capture stormwater runoff to prevent the discharge of pollutants, including "unpolluted" fresh water, to sensitive coastal receiving waters and wetlands. The runoff capture criterion applies to new stormwater discharges located less than 500 feet from tidal wetlands, which are not fresh-tidal wetlands. The stormwater runoff volume generated by the first inch of rainfall must be retained on-site for such discharges. The runoff capture volume is equivalent to the WQV and can be calculated using the following equation:

Table 7-5 Land Uses or Activities with Potential for Higher Pollutant Loads

Land Use/Activities	
Industrial facilities subject to the DEP Industrial Stormwater General Permit or the U.S. EPA National Pollution Discharge Elimination System (NPDES) Stormwater Permit Program[1]	Road salt storage facilities (if exposed to rainfall)
Vehicle salvage yards and recycling facilities	Commercial nurseries
Vehicle fueling facilities (gas stations and other facilities with on-site vehicle fueling)	Flat metal rooftops of industrial facilities
Vehicle service, maintenance, and equipment cleaning facilities	Facilities with outdoor storage and loading/unloading of hazardous substances or materials, regardless of the primary land use of the facility or development
Fleet storage areas (cars, buses, trucks, public works)	Facilities subject to chemical inventory reporting under Section 312 of the Superfund Amendments and Reauthorization Act of 1986 (SARA), if materials or containers are exposed to rainfall
Commercial parking lots with high intensity use (shopping malls, fast food restaurants, convenience stores, supermarkets, etc.)	Marinas (service and maintenance)
Public works storage areas	Other land uses and activities as designated by the review authority

[1] Stormwater pollution prevention plans are required for these facilities. Pollution prevention and source controls are recommended for the other land uses and activities listed above.

$$RCV = \frac{(1'')(R)(A)}{(12)}$$

where: RCV = runoff capture volume (acre-feet)
R = volumetric runoff coefficient
I = percent impervious cover
A = site area in acres

Wet ponds designed with adequate storage volume to capture and retain the RCV or infiltration practices described in this Manual can be used to satisfy the runoff capture volume criterion.

Rationale

The runoff capture volume criterion is consistent with DEP coastal management policy and stormwater general permit requirements. Discharge of the "first-flush" of stormwater runoff into brackish and tidal wetlands is prohibited due to the resultant dilution of the high marsh salinity and encouragement of the invasion of brackish or upland wetland species such as Phragmites.

7.6 Peak Flow Control

Peak flow control criteria are intended to address increases in the frequency and magnitude of a range of potential flood conditions resulting from development. These include relatively frequent events that cause channel erosion, larger events that result in bankfull and overbank flooding, and extreme floods. The following sections describe sizing criteria for controlling peak flows, as well as for designing stormwater conveyance and emergency outlet structures. Natural Resource Conservation Service (NRCS) peak flow calculation methods such as TR-55 or TR-20 should be used to compute the required peak flow rates for each of the criteria described below.

7.6.1 Stream Channel Protection

Description

The stream channel protection criterion is intended to protect stream channels from erosion and associated sedimentation in downstream receiving waters and wetlands as a result of urbanization within a watershed. By restricting peak flows from storm events that result in bankfull flow conditions (typically the 2-year storm, which controls the form of the stream channel), damaging effects to the channel from increased runoff due to urbanization can be reduced.

Either of the following two methods can be used to satisfy the stream channel protection criterion. Both rely on "over-control" of the two-year frequency design storm:

- *Control the 2-year, 24-hour post-development peak flow rate to 50 percent of the 2-year, 24-hour pre-development level or*
- *Control the 2-year, 24-hour post-development peak flow rate to the 1-year, 24-hour pre-development level*

There are several practical limitations on the application of the stream channel protection criterion. For sites having less than one acre of impervious cover, the size of the orifice or weir required for extended detention becomes too small (approximately 1 inch in diameter) to effectively operate without clogging. In addition, channel protection is generally not required where sites discharge to a large receiving water body (Brown and Caraco, 2001). Therefore, the channel protection criterion does not apply under the following conditions:

- *The entire channel protection volume is recharged to groundwater*
- *Sites less than or equal to one acre of impervious cover*
- *The site discharges to a large river (fourth order or greater), lake, estuary, or tidal water where the development area is less than 5 percent of the watershed area upstream of the development site unless known water quality problems exist in the receiving waters. Stream order indicates the relative size of a stream based on Strahler's (1957) method. Streams with no tributaries are first order streams, represented as the start of a solid line on a 1:24,000 USGS Quadrangle Sheet. A second order stream is formed at the confluence of two first order streams, and so on.*

Rationale

A number of design criteria have been developed for the purpose of stream channel protection. The earliest and most common method relied on control of post-development peak flows associated with the 2-year, 24-hour storm event to pre-development levels based on the assumption that bankfull discharge for most streams has a recurrence interval of between 1 and 2 years (Leopold, et al., 1964 and Leopold, 1994). More recent research indicates that this method does not adequately protect stream channels from downstream erosion and may actually contribute to erosion since banks are exposed to a longer duration of erosive bankfull and sub-bankfull events (MacRae, 1993 and 1996, McCuen and Moglen, 1988).

The two-year "over-control" methods recommended above were developed as a modification of the original two-year control approach to provide additional protection. These methods require larger detention volumes than the traditional two-year approach, but reduce the duration of bankfull flows. More recent research has shown that extended detention of the 1-year, 24-hour storm event and a method referred to as Distributed Runoff Control (DRC) potentially provide the highest level of stream channel protection. In the extended detention method, the runoff volume generated by the 1-year, 24-hour rainfall (2.6 to 2.7 inches in Connecticut) is captured and gradually released over a 24-hour period to control erosive velocities in downstream channels. However, this method results in extremely large detention storage requirements (comparable to the storage volume required for 10-year peak discharge control), and the incremental benefits of this approach over the two-year over-control approach are undocumented. The DRC method involves detailed field assessments and hydraulic/hydrologic modeling to determine hydraulic stress and erosion potential of stream banks. This level of detailed, site-specific analysis is not warranted for use as a general stream channel protection criterion.

7.6.2 Conveyance Protection

Description

The conveyance systems to, from, and through stormwater management facilities should be designed based on the peak discharge rate for the 10-year, 24-hour storm. This criterion is designed to prevent erosive flows within internal and external conveyance systems associated with stormwater treatment practices such as channels, ditches, berms, overflow channels, and outfalls. The local review authority may require the use of larger magnitude design storms for conveyance systems associated with stormwater treatment practices.

Rationale

This criterion is generally consistent with storm drainage system design in Connecticut, including design requirements of most municipalities and the Connecticut Department of Transportation.

7.6.3 Peak Runoff Attenuation

Description

The peak runoff attenuation criterion is designed to address increases in the frequency and magnitude of flooding caused by development. This criterion is intended to control a range of flood conditions, from events that just exceed the bankfull capacity of the stream channel to catastrophic flooding associated with extremely large events. Other objectives include maintaining the boundaries of the pre-development 100-year floodplain and protecting the physical integrity of stormwater management facilities.

The recommended peak runoff attenuation criterion in Connecticut includes control of post-development peak discharge rates from the 10-year, 25-year, and 100-year storms to the corresponding pre-development peak discharge rates, as required by the local review authority. Attention must be given to timing of peak flows. The local review authority may require peak runoff attenuation for additional design storms such as the 1-year, 2-year, 5-year and 50-year, 24-hour events. The local review authority may waive the peak runoff attenuation criterion for sites that discharge to a large river (fourth order or greater), lake, estuary, or tidal waters where the development area is less than 5 percent of the watershed area upstream of the development site.

Rationale

This criterion is generally consistent with storm drainage system design in Connecticut, including design requirements of most municipalities and the Connecticut Department of Transportation.

7.6.4 Emergency Outlet Sizing

Description

The emergency outlets of stormwater management facilities should be designed to safely pass the peak discharge rate associated with the 100-year storm or larger. The emergency outlet should be able to pass the 100-year peak runoff rate, at a minimum, in a controlled manner, without eroding outfalls or downstream conveyances. Emergency outlets constructed in natural ground are generally preferable to constructed embankments. This criterion is applicable to all stormwater management facilities that employ an emergency outlet.

Rationale

This criterion is generally consistent with storm drainage system design in Connecticut, including design requirements of most municipalities and the Connecticut Department of Transportation.

7.6.5 Downstream Analysis

Peak runoff control criteria are typically applied at the immediate downstream boundary of a project area. However, since stormwater management facilities may change the timing of the post-development hydrograph, multiple stormwater treatment practices or detention facilities in a watershed may result in unexpected increases in peak flows at critical downstream locations such as road culverts and areas prone to flooding. This effect is most pronounced for detention structures in the middle to lower third of a watershed. The local review authority may require a downstream analysis to identify potential detrimental effects of proposed stormwater treatment practices and detention facilities on downstream areas.

The downstream analysis should include the following elements:

- *Routing calculations should proceed downstream to a confluence point where the site drainage area represents 10 percent of the total drainage area (i.e., the "10 percent rule")*
- *Calculation of peak flows, velocities, and hydraulic effects at critical downstream locations (stream confluences, culverts, other channel constrictions, and flood-prone areas) to the confluence point where the 10 percent rule applies*
- *The analysis should use an appropriate hydrograph routing method, such as TR-20, to route the pre- and post-development runoff hydrographs from the project site to the downstream critical locations*

The ultimate objective of this analysis is to ensure that proposed projects do not increase post-development peak flows and velocities at critical downstream locations in the watershed. Increases in flow rates and velocities at these locations should be limited to less than 5 percent of the pre-developed condition (NYDEC, 2001) and should not exceed freeboard clearances or allowable velocities.

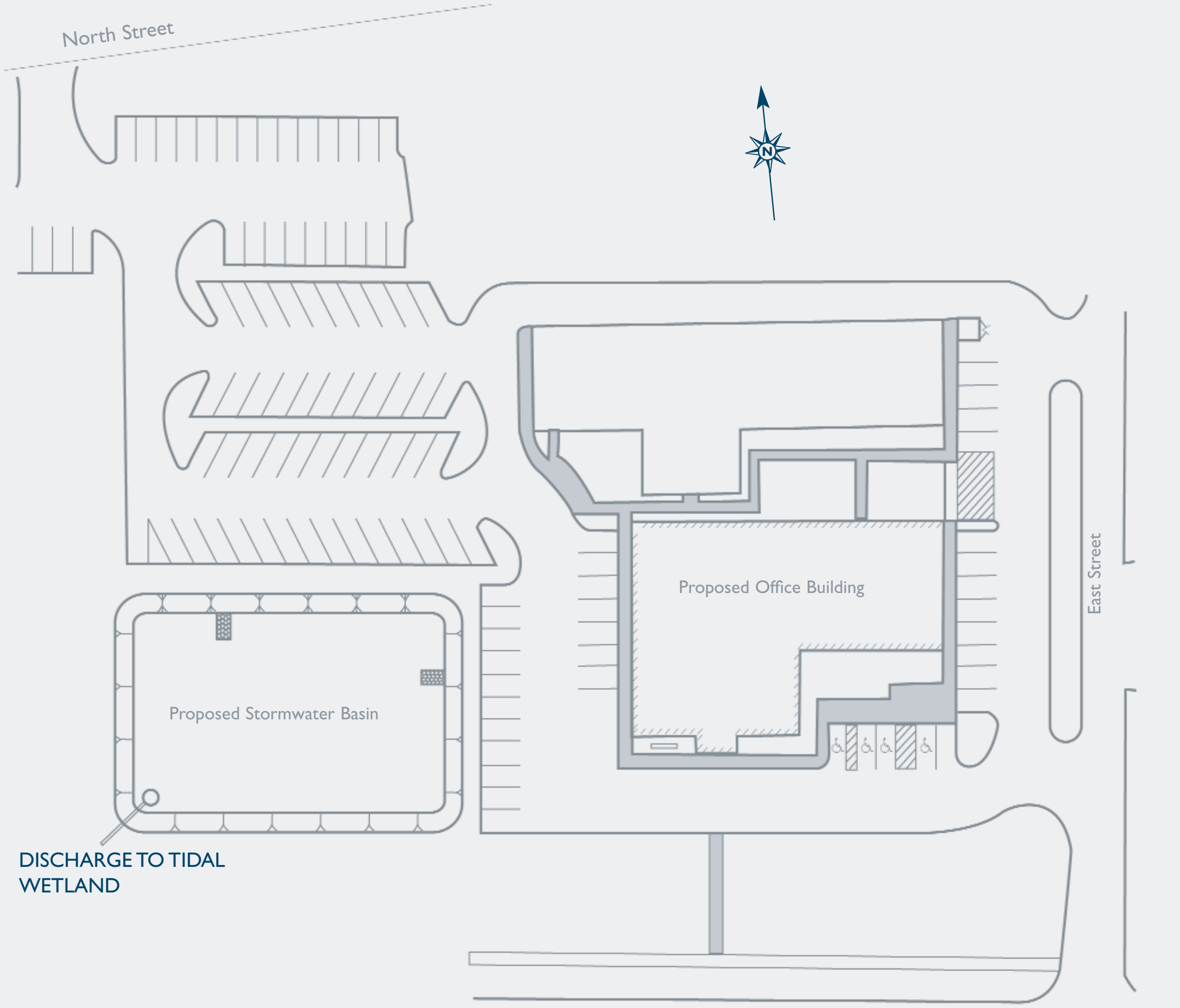
7.7 Sizing Example

The following example illustrates how the various sizing criteria described in this chapter are applied to determine stormwater treatment requirements (required storage volume and hydraulic capacity) for a hypothetical development project.

Old Town Office Building, New London, Connecticut

An office building is proposed on a commercial property in New London, Connecticut. The approximately 2-acre site is characterized by Type B soils. The proposed development consists of approximately 80 percent impervious area (parking lots and buildings), with approximately 20 percent as lawn or undisturbed area. Runoff from the impervious areas is collected and conveyed to a hypothetical stormwater treatment basin located on the southwest portion of the site. Stormwater is discharged from the basin to an adjacent tidal wetland. **Figure 7-1** shows a schematic layout of the proposed development.

Figure 7-1 Sizing Example – Proposed Old Town Office Building



Project Data

Location: New London, CT
Total Drainage Area (A)
Existing = 1.98 Ac; Proposed = 2.40
Impervious Area = 1.92 Ac; or I = 1.92/2.40= 80.0 %
Site Soil Type: "B"
Zoning: Business
Discharge to tidal wetlands

Hydrologic Data

	Pre-Development	Post-Development
CN	82	92
Tc (hr)	0.25	0.17

Source: Fuss & O'Neill, Inc.

1. *Water Quality Volume*

a. Compute volumetric runoff coefficient, R

R = $0.05+0.009(I)$
= $0.05+0.009(80)$
= $\underline{0.77}$

b. Compute water quality volume, WQV

WQV = $(1")(R)(A)/12$
= $(1")(0.77)(2.40)/12$
= $\underline{0.15 \text{ ac-ft}}$

2. *Water Quality Flow*

Compute the water quality flow (WQF) for off-line stormwater treatment.

a. Compute the runoff depth, Q

$$Q = \frac{[WQV(acre-feet)] \text{ x } [12(inches/foot)]}{Drainage\ Area\ (acres)}$$

$$= \frac{(0.15)\text{x}[12(inches/foot)]}{2.40}$$

= $\underline{0.77 \text{ in}}$

b. Compute the NRCS Runoff Curve Number (CN)

$$CN = \frac{1000}{\left[10 + 5P + 10Q - 10\left(Q^2 + 1.25QP\right)^{1/2}\right]}$$

$$= \frac{1000}{\left[10 + 5(1) + 10(0.77) - 10\left((0.77)^2 + 1.25\ (0.77)(1)\right)^{1/2}\right]}$$

= $\underline{98}$

c. Read initial abstraction, I_a (Table 4-1 in Chapter 4, TR-55)
I_a = 0.041

d. Compute I_a/P
= 0.041/1
= $\underline{0.041}$

e. Read initial abstraction, q_u (Exhibit 4-11 in Chapter 4, TR-55)
q_u = 580 csm/in (Type III storm)

f. Compute water quality flow (WQF)
WQF = $(q_u)(A)(Q)$
= $(580)(0.004)(0.77)$
= $\underline{1.8 \text{ cfs}}$

3. *Groundwater Recharge Volume*

Compute the groundwater recharge volume (*GRV*) using the hydrologic soil group approach.

a. Read runoff depth to be recharged, D (Table 7-4)
D = <u>0.25 in</u>

b. Compute net increase in site imperviousness, I (proposed) – I (existing)
I = 0.80-0.44
= <u>0.36</u>

c. Compute groundwater recharge volume, *GRV*

$$GRV = \frac{(D)(A)(I)}{12}$$

$$= \frac{(0.25)(2.40)(0.36)}{12}$$

$$= \underline{0.018 \text{ ac-ft}}$$

4. *Runoff Capture Volume*

Compute the runoff capture volume (*RCV*) since the site discharges stormwater within 500 feet of tidal wetlands.

$$RCV = \frac{(1")(R)(A)}{(12)}$$

$$= \frac{(1")(0.77)(2.40)}{(12)}$$

$$= \underline{0.15 \text{ ac-ft}}$$

5. *Stream Channel Protection*

Compute the required stream channel protection discharge using both "Two-Year Over-Control" methods recommended in Section 7.6.1.

a. Method-1, control the 2-year, 24-hour post-development flow to 50% of the 2-year, 24-hour pre-development flow

$Q_{2(control)}$ = (0.5) $Q_{2(exist)}$
= (0.5)(2.2)
= 1.1 cfs
$Q_{2(proposed)}$ = <u>0.9 cfs</u>
$Q_{2(proposed)} < Q_{2(control)}$, meets method-1 criteria

b. Method-2, control the 2-year, 24-hour post-development flow to the 1-year, 24-hour pre-development flow

$Q_{1(exist)}$ = 1.8 cfs
$Q_{1(exist)} > Q_{2(proposed)}$, meets method-2 criteria

6. *Conveyance Protection*

Site storm drainage conveyance system designed for a 10-yr, 24-hour post-development peak flow, Q10.

Q_{10} = <u>4.3 cfs</u>

7. *Peak Runoff Attenuation*

From TR-55 peak discharge summary worksheets:

Storm Event	Pre-Development (cfs)	Post Development (cfs)
10-year	4.3	4.0
25-year	5.3	5.2
100-year	6.8	9.8

8. *Emergency Outlet Sizing*

Safe passage of the 100-year storm event under proposed conditions requires passing Q_{100} of 9.8 cfs through the proposed stormwater basin emergency spillway. The spillway is designed to safely convey 9.8 cfs without causing a breach of the stormwater basin that would otherwise damage downstream areas or present a safety risk.

Summary of Sizing Requirements

Criterion	Requirement
Water Quality Volume	0.15 ac-ft
Water Quality Flow	1.8 cfs
Groundwater Recharge Volume	0.018 ac-ft
Runoff Capture Volume	0.15 ac-ft
Stream Channel Protection	0.9 cfs (2-year "over-control")
Conveyance Protection	4.3 cfs (10-year)
Peak Runoff Attenuation	5.3 cfs (25-year)
Emergency Outlet Sizing	9.8 cfs (100-year)

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Chapter 8
Selection Criteria for Stormwater Treatment Practices

Volume II: Design

Chapter 8

Selection Criteria for Stormwater Treatment Practices

8.1 Stormwater Management Effectiveness

As discussed in Chapter Two, land development increases the potential for several stormwater related impacts. These impacts are largely a function of altering the natural hydrology at a site and increasing exposure to potential pollutants. Common stormwater impacts related to land development include degraded water quality, increased peak flow rates, increased runoff volume, stream channel erosion, and reduced groundwater recharge.

No single stormwater treatment practice is appropriate for every site and condition. The applicability of individual practices varies depending upon relatively simple physical constraints, as well as more complicated siting and treatment issues. This chapter addresses criteria to consider when selecting stormwater treatment practices for a particular site.

As discussed in Chapter Seven, stormwater treatment practices can achieve one or more of the following management objectives:

- *Pollutant reduction*
- *Groundwater recharge and runoff volume reduction*
- *Stream channel protection and peak flow control*

Table 8-1 summarizes the relative effectiveness of each stormwater treatment practice in providing these management capabilities. The effectiveness ratings provided in the table should only be used to compare the relative management capabilities of different treatment practices. The ratings should not be used in an absolute sense to quantitatively predict actual field performance.

As described in Chapter Six, there is currently a lack of reliable performance data for stormwater treatment practices in the State of Connecticut. Additionally, the available performance data from past monitoring studies conducted throughout the United States are limited by differences in design, performance goals, site parameters, storm events, flow and pollutant loadings, seasonal variations, monitoring methods, and efficiency calculation methods or simply by the lack of, or inadequate, information. The reliability of pollutant removal efficiencies, which are often cited in guidance documents, is typically poor due to the large degree of uncertainty in the data. Additional performance monitoring using standardized methods and quality control procedures is recommended for new and existing stormwater treatment practices (see Chapter Six) in Connecticut to provide a more useful set of data on the effectiveness of individual stormwater treatment practices, and to better understand the relationship between treatment practice design and performance.

As shown in **Table 8-1**, most of these primary treatment practices are similarly effective at removing sediment, nutrients, and metals. Removal efficiencies are generally highest for sediment, while nutrient and metals removal efficiencies are typically lower. Infiltration systems are generally the most effective practices for removal of bacteria. Designs that incorporate floatable controls or pretreatment are most effective for removal of hydrocarbons. Treatment practices that incorporate biological removal mechanisms, such as constructed wetlands, are also more effective in removing pollutants than systems that strictly rely on gravity or physical separation of particles.

Many of these practices also have limited effectiveness in terms of peak flow control and groundwater recharge. Open bottom basins and dry swales provide some groundwater recharge, but only practices specifically designed as infiltration structures will provide significant levels of groundwater recharge. Many of these practices either have an impermeable bottom or are designed to intercept groundwater and thereby provide little infiltration. Similarly, attenuation of peak flows requires significant available storage capacity to temporarily store runoff as the peak flow is being throttled. Many stormwater treatment practices provide limited storage capacity or detention time and are inadequate as stand-alone flood

Table 8-1 Stormwater Management Effectiveness Criteria

Category	Practice	Pollutant Reduction: Sediment	Total P	Total N	Metals	Hydro Carbons	Bacteria	Ground Water Recharge/ Runoff Volumn Reduction	Stream Channel Protection	Peak Flow Control
Stormwater Ponds	Wet pond	●	●	●	●	●	◐	○	●	●
	Micropool ED pond							◐	●	●
	Wet ED pond							◐	●	●
	Multiple pond system							○	●	●
Stormwater Wetlands	Shallow wetland	●	●	●	◐	●	●	○	●	◐
	ED wetland							○	●	●
	Pond/wetland system							○	●	●
Infiltration Practices	Infiltration trench	●	●	●	●	◐	●	●	◐	○
	Infiltration basin							●	●	◐
Filtering Practices	Surface sand filter	●	●	●	●	●	◐	◐[1]	◐	○
	Underground sand filter							○	○	○
	Perimeter sand filter							○	○	○
	Bioretention							◐[1]	◐	○
Water Quality Swales	Dry swale	●	◐	◐	●	◐	○	◐[1]	○	○
	Wet swale							○	○	○

Notes: ● Effective
◐ Somewhat effective
○ Least effective

[1]If designed as exfilter
ED – Extended Detention

Source: Adapted from Winer, 2000; EPA 1993; and ASCE and Wright Water Engineers, Inc., 2001.

control facilities. Separate facilities for peak flow control are often necessary to augment stormwater treatment practices.

A treatment train approach should be considered when selecting treatment practices for a particular site when faced with several sometimes competing demands. As discussed in Chapter Six, a treatment train consists of a series of management practices each designed to provide targeted pollution control benefits. For example, one practice may be selected for its ability to remove sediments while another may be better suited to remove dissolved pollutants.

8.2 Land Use Factors

Land use, both current and potential future use, should be considered when selecting stormwater treatment practices. Some practices are more "neighbor friendly" than others. Other practices are more land intensive and may be less desirable where space is at a premium. The following land use factors should be considered when selecting stormwater treatment practices.

Rural

Rural areas are typically characterized by low-density development (i.e., few neighbors) and relatively large amounts of available space. Stormwater treatment practices with larger area demands may be easier to locate with appropriate buffers in rural areas. Additionally, typical stormwater pollutants from rural areas include sediments and nutrients, which can be effectively managed by most stormwater treatment practices. As a result, most treatment practices are suitable for rural areas.

Residential

Medium- to high-density residential areas typically have limited space and higher property values compared to rural undeveloped areas. Also, treatment practices in these areas are likely to be located in close proximity to residences. Public safety and nuisance insects are common concerns for treatment practices in residential areas. Stormwater treatment practices with large land requirements or open pools of water may be less desirable in these areas. In some situations, stormwater ponds or other open water practices may be incorporated into the landscape as natural amenities to provide habitat, recreation, and aesthetic value.

Roads and Highways

Roads and highways typically generate high stormwater pollutant loads due to vehicle traffic and winter deicing activities. Sediments, metals, chlorides, and hydrocarbons are the primary pollutants associated with roads and highways. Nitrogen from vehicle exhausts and bacteria are also commonly present in road and highway runoff. As a result, most treatment practices provide some treatment benefit but do not adequately address all of the water quality impacts associated with this land use. In addition, open water and deep pools can also be a safety issue near roads and highways.

Commercial and Industrial Development

Commercial and industrial areas often have more intensive traffic, increased risk of spills, and exposure of materials to precipitation. Pollutants associated with these land uses can vary significantly depending on the nature of activities at each site, although traffic-related pollutants such as sediments, metals, and hydrocarbons are commonly present in runoff from most commercial and industrial sites. These developments may also have more available space for locating stormwater treatment practices.

Ultra-Urban Sites

Ultra-urban sites are the most restrictive in terms of treatment practice selection. These sites are characterized as having little available space or land area, high population density, and a wide range of potential pollutants.

Table 8-2 summarizes the compatibility of stormwater treatment practices with each of the above land uses, considering potential pollutants, public safety, nuisance insects, and land availability.

Table 8-2 Land Use Selection Criteria

Category	Practice	Rural	Residential	Roads and Highways	Commercial/ Industrial	Ultra Urban[3]
Stormwater Pond	Wet pond	●	❍	●	●[2]	❍
	Micropool extended detention pond	●	◍	●	●[2]	❍
	Wet extended detention pond	●	◍	●	●[2]	❍
	Multiple pond system	●	❍	◍	●[2]	❍
Stormwater Wetlands	Shallow wetland	●	❍	●	●[2]	❍
	Extended detention wetland	●	❍	●	●[2]	❍
	Pond/wetland system	●	◍	◍	◍[2]	❍
Infiltration Practices	Infiltration trench	◍	◍	◍	◍	❍
	Infiltration basin	●	◍	●	●	❍
Filtering Practices	Surface sand filter	◍	●	●	●[1]	❍
	Underground sand filter	❍	◍	●	●	●
	Perimeter sand filter	❍	❍	❍	◍	◍
	Bioretention	◍	◍	●	●[1]	◍
Water Quality Swales	Dry swale	●	●	●	◍[1]	❍
	Wet swale	●	◍	●	◍	❍

Notes:
● Appropriate
◍ Somewhat appropriate
❍ Least appropriate

[1]If not designed to infiltrate
[2]May require pond liner
[3]Secondary treatment practices and stormwater treatment trains are typically more appropriate for Ultra Urban land uses

Source: Adapted from NYDEC, 2001.

8.3 Physical/Site Feasibility Factors

Physical site constraints can also dictate the feasibility of specific stormwater treatment practices. These physical constraints can either make the installation of a particular treatment practice too costly or result in reduced or ineffective operation. While every site has its own individual characteristics that need to be evaluated, the five most common physical constraints that need to be considered are:

- *Infiltration capacity*
- *Seasonally high groundwater (water table)*
- *Drainage area*
- *Slope*
- *Required hydraulic head*

These factors are discussed in general terms below. Chapter Eleven contains additional information on physical feasibility and siting considerations for individual treatment practices.

Infiltration Capacity

Infiltration practices are highly dependent on the infiltration capacity of the underlying soils. Low soil infiltration capacity requires structures with larger infiltration surface area and storage capacity to account for slower infiltration rates. Higher soil infiltration rates allow for smaller infiltration structures. Accurate field measurements of infiltration rates are critical for the successful design and implementation of stormwater treatment practices that rely on infiltration of stormwater to underlying soils.

In Connecticut, the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) has developed soil suitability rankings for various types of stormwater management practices, including infiltration trenches, underground infiltration galleries, stormwater wetlands, and stormwater ponds. The soil suitability designations are intended to facilitate proper selection and siting of stormwater controls and are based upon NRCS soil survey soil properties and landscape criteria. The information can be used to generate soil suitability maps for a town, watershed, or other designation. Soils are rated for each practice (suitable, fair, or good), and the specific limitations (slow infiltration, for example) are provided. This tool is intended to be used for initial screening of stormwater treatment practices and does not eliminate the need for on-site evaluation of soil characteristics for design purposes. Additional information on this program can be obtained from the Connecticut USDA NRCS (see Additional Information Sources at the end of this chapter).

Water Table

An elevated water table poses several design issues. The primary issue is the loss of storage and retention capacity in unlined treatment structures. If seasonally high groundwater exists above the bottom of an unlined pond or basin, groundwater will drain into the structure and fill or displace volume that may have been intended for retention. If a treatment practice is constructed below the seasonally high water table, the loss of storage capacity should be accounted for in the design, or engineering controls such as liners and/or underdrains should be considered.

An elevated water table may be advantageous for some treatment practices where a permanent pool of water is desired, such as stormwater wetlands. However, small separation between the bottom of a treatment structure and the water table may result in inadequate pollutant attenuation and treatment in the unsaturated zone. The potential for groundwater pollution due to stormwater infiltration is an important consideration in the design of stormwater treatment practices. Engineering controls such as impermeable liners may be required in these circumstances.

Buoyancy of structures installed below the water table is another issue related to a high water table. Below the water table, buoyancy is calculated as the weight of water displaced (i.e., the volume of the structure below the water table multiplied by the unit weight of fresh water or 62.4 pounds per cubic foot). The upward buoyant force may be large enough to displace a structure, sometimes out of the ground. Engineering controls typically consist of anchors, such as connecting the structure to an appropriately sized concrete pad to provide adequate weight to offset buoyant forces.

Field determination of seasonally high groundwater is required for the successful design and implementation of most stormwater treatment practices.

Drainage Area

The efficiency of most treatment practices decreases with increasing drainage area and volume of stormwater runoff. An increased hydraulic load can increase velocities and reduce detention time in a treatment structure. The size of some practices can be increased to address the issues associated with an increased hydraulic load. Other treatment practices are better suited to smaller drainage areas and smaller hydraulic loads. One approach to improving the efficiency of practices serving larger drainage areas is to construct diversion structures for treatment of the Water Quality Volume, while larger flows or volumes are bypassed around the treatment system.

Slope

The ground slope at and immediately adjacent to the location of a treatment practice, as well as the slope of the contributing watershed and drainage flow paths, are important factors in determining the feasibility of treatment controls. Most stormwater treatment practices are sensitive to the local terrain slope. For example, swales and infiltration basins cannot be used in steep terrain, while others such as stormwater ponds and filtering practices can be adapted to most terrain. The slope of the contributing drainage area or watershed can influence erosion and sediment loads to the treatment system. Many stormwater treatment practices are not recommended for sites with significant sediment loads without suitable pretreatment.

Required Head

Several practices, such as stormwater filtering systems, require larger hydraulic head for gravity flow to and through the system. For example, if only four feet of grade exists on a site between the most hydraulically remote point on the site and the invert elevation of the discharge, a treatment practice that requires five feet of head would not be feasible.

Table 8-3 summarizes the physical feasibility criteria discussed above.

8.4 Downstream Resources

While all sites should provide at least a minimum level of protection, stormwater treatment practices should be tailored not only to the conditions that exist at a particular site, but also to the downstream resources that could be impacted by stormwater discharges from the site. As a result, the following downstream resources should be considered in the treatment practice selection process.

Sensitive Watercourses

Streams, brooks, and rivers that are classified by DEP as Class A (fishable, swimmable, and potential drinking water), as well as their tributary watercourses and wetlands, are high quality resources that warrant a high degree of protection. Toxic pollutants such as metals and soluble organics, as well as other contaminants such as bacteria, are the primary concern for these waterbodies. Sensitive cold water fisheries, including Class B waters or managed stocked streams, could also be adversely impacted by stormwater runoff with elevated temperatures. In addition, the rate and volume of stormwater discharges from new developments are especially critical to these systems, as they could impact the flood carrying capacity of the watercourse and increase the potential for channel erosion.

Water Supply Aquifers

Groundwater is a major source of drinking water in Connecticut for residences that rely on small private wells and larger water distributors. This applies to both water supply aquifers and Class GA and GAA groundwaters as defined by DEP. In addition, groundwater is the source of dry weather flows (baseflow) in watercourses, which is critical for maintaining suitable habitat. As a result, it is important to maintain groundwater recharge, and to maintain a high quality recharge to groundwater in water supply aquifers and Class GA and GAA waters.

Lakes and Ponds

Lakes and ponds are especially sensitive to sediment and nutrient loadings. Excess sediments and nutrients are the cause of algal blooms in these surface waters, leading to eutrophication and degradation. These conditions often result in costly dredging and rehabilitation projects. In fresh water systems, phosphorus is typically the limiting nutrient, that is, much less phosphorus is needed compared to other nutrients such as nitrogen to create eutrophic conditions. As a result, treatment practices should focus on nutrient removal, particularly phosphorus, for stormwater discharges to lakes and ponds, and watercourses that feed lakes and ponds. Control of phosphorus is also directly related to the control of iron. Certain iron compounds such as ferric iron often have a high scavenging coefficient for metals. Thus, control of phosphorus may have ancillary benefits in the control of metals.

Surface Water Drinking Supplies

Surface waters that supply drinking water are especially susceptible to contamination by bacteria and other pathogens. Other contaminants-of-concern may be defined for specific water supply systems by the owner/operator or the State Department of Health. Treatment practices for sites within drinking water supply watersheds should target these potential contaminants. The Public Health Code also requires a 100-foot separation distance between drainage or treatment practice outlets and public water supply tributaries. Site designs within public water supply watersheds are encouraged to maximize absorption of pollutants by the soil and vegetation.

Estuary/Coastal

Coastal or estuary areas are more sensitive to nitrogen loadings than fresh water systems. In salt water systems, nitrogen tends to be the limiting nutrient as opposed to phosphorus. Bacteria are also a concern given the sensitivity of public swimming areas and shellfish beds to bacterial loadings.

Table 8-4 summarizes limitations and engineering considerations for stormwater treatment practices based on downstream resources and the receiving environment.

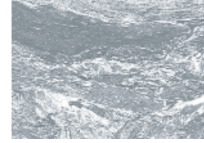

Table 8-3 Physical Feasibility Criteria

Category	Practice	Soil Infiltration Capacity	Seasonally High Water Table	Drainage Area (acres)	Slope	Required Head
Stormwater Ponds	Micropool ED pond	USDA Hydrologic Soil Group A and B soils may require pond liner unless groundwater intercepted	Construct below water table. Construct liner for sites with higher potential pollutant loads or water supply aquifers.	10 min[1]	15% max	4 to 8 ft
	Wet Pond			25 min[1]		
	Wet ED pond			1-5 max[2] (pocket pond)		
	Multiple pond system					
Stormwater Wetlands	Shallow wetland	USDA Hydrologic Soil Group A and B soils may require pond liner unless groundwater intercepted	Construct below water table. Use liner for sites with higher potential pollutant loads or water supply aquifers	10 min	8% max	2 to 5 ft
	ED wetland			5 max[2] (pocket wetland)		
	Pond/wetland system					
Infiltration Practices	Infiltration trench	Min field measured infiltration rate 0.3 in/hr. Max infiltration rate 5.0 in/hr. Pretreatment required over 3.0 in/hr	Bottom of facility 3 feet above seasonally high water table	2 max[2]	15% max	1 ft
	Infiltration basin			10 max[2]		3 ft
Filtering Practices	Surface sand filter	Unrestricted	Underdrain for unlined system 2 feet above seasonally high water table	25 max[2]	6% max	5 ft
	Underground sand filter			10 max[2]		5 to 7 ft
	Perimeter sand filter			2 max[2]		2 to 3 ft
	Bioretention			5 max[2]		2 to 5 ft
Water Quality Swales	Dry Swale	Unrestricted	Swale bottom 2 to 4 feet above seasonally high water table	5 max[2]	5% max	3 to 5 ft
	Wet Swale	Unrestricted	At or below seasonally high water table	5 max[2]		<1 ft

Notes: [1]Unless adequate water balance
[2]Drainage area can be larger if appropriately designed
ED – Extended Detention

Source: Adapted from NYDEC, 2001.

Table 8-4 Downstream Resource Selection Criteria (A)

Category	Practice	Sensitive Watercourses	Water Supply Aquifers	Lakes and Ponds
Stormwater Ponds	Micropool extended detention pond Wet pond Wet extended detention pond Multiple pond system	Restrict in-stream practices Minimize permanent pool area, and encourage shading to reduce thermal impacts	Require liner if USDA Hydrologic Soil Group A soils are present or <2 ft separation to seasonally high groundwater	Encourage the use of a large permanent pool to increase residence time to improve phosphorus removal
Stormwater Wetlands	Shallow wetland Extended detention wetland Pond/wetland system	Restrict use or utilize shading	Pretreat runoff from land uses or sites with the potential for high pollutant loadings	
Infiltration Practices	Infiltration trench Infiltration basin	Encourage use to maximize groundwater recharge Combine with a detention facility to provide flood control and channel protection	Provide 100 ft horizontal separation distance from wells and 3 ft vertical distance from the seasonally high water table, 4 ft from bedrock Pretreat runoff from all land uses prior to infiltration	OK, provides high phosphorus removal
Filtering Practices	Surface sand filter Underground sand filter Perimeter sand filter Bioretention	Combine with a detention facility to provide flood control and channel protection	Excellent pretreatment for infiltration or open channel practices	OK, but designs with a submerged filter bed may result in phosphorus release
Water Quality Swales	Dry swale Wet swale	Combine with a detention facility to provide flood control and channel protection	OK, but pretreat runoff from land uses or sites with the potential for high pollutant loadings	OK, moderate phosphorus removal

Table 8-4 Downstream Resource Selection Criteria (B)			
Category	**Practice**	**Surface Water Drinking Supplies**	**Estuary/ Coastal**
Stormwater Ponds	Micropool extended detention pond	Encourage the use of a large permanent pool to improve phosphorus removal Promote long detention times to encourage pollutant removal Provide 100 ft separation distance from outlet to public water supply tributary	Encourage long detention times to promote pollutant removal Consider tidal elevations More effective for removal of inorganic nitrogen and ammonia; less effective for organic nitrogen removal
	Wet pond		
	Wet extended detention pond		
	Multiple pond system		
Stormwater Wetlands	Shallow wetland	Encourage the use of a large permanent pool to improve phosphorus removal Promote long detention times to encourage bacteria removal Provide 100 ft separation distance from outlet to public water supply tributary	Encourage long detention times to promote pollutant removal Consider tidal elevations
	Extended detention wetland		
	Pond/wetland system		
Infiltration Practices	Infiltration trench	Provide 4 ft separation distance to bedrock and 3 ft to seasonally high water table Pretreat runoff prior to infiltration practices	OK, but provide 3 ft separation distance to seasonally high groundwater
	Infiltration basin		
Filtering Practices	Surface sand filter	Excellent pretreatment for infiltration or open channel practices Moderate to high bacteria removal Provide 100 ft separation distance from outlet to public water supply tributary	Moderate to high bacteria removal Designs with a submerged filter bed appear to provide high nitrogen removal
	Underground sand filter		
	Perimeter sand filter		
	Bioretention		
Water Quality Swales	Dry swale	Pretreat runoff Minimal bacteria removal Provide 100 ft. separation distance from outlet to public water supply tributary	Pretreat runoff Minimal bacteria removal
	Wet swale		

Source (Tables 8-4 A and B): Adapted from NYDEC, 2001.

8.5 Maintenance Factors

Regular maintenance is required for the successful long-term operation of any stormwater treatment practice. Accumulated sediment and floatables reduce pollutant removal efficiencies and increase the potential for resuspension as well as sediment reflux. Accumulated debris can also impact hydraulic performance. Some treatment practices require more intensive or more frequent maintenance in order to function as designed. For example, the filter bed of a sand filter needs to be replaced when clogged, and stormwater wetlands need to be "harvested" periodically.

Table 8-5 summarizes the maintenance requirements for stormwater treatment practices. Maintenance sensitivity is a measure of a practice's susceptibility to reduced performance if not adequately maintained.

8.6 Winter Operation

In Connecticut, the effects of winter conditions (cold temperatures, snow, ice, etc.) on stormwater treatment practice performance are important considerations. While there may be fewer runoff events during winter months, snow and ice may significantly impact the operation of some treatment practices during winter

Table 8-5 Maintenance Criteria

Category	Practice	Maintenance Sensitivity	Inspections	Sediment Removal	Other
Stormwater Ponds	Micropool extended detention pond	❍	❍	◍	Aging ponds become ineffective and may become pollutant sources in some cases; decadal evaluations are considered minimal; more frequent dredging may be required in developing watersheds with significant sediment loads
	Wet pond	❍	❍	◍	
	Wet extended detention pond	❍	❍	◍	
	Multiple pond system	❍	❍	◍	
Stormwater Wetlands	Shallow wetland	◍	◍	●	Requires periodic harvesting to maximize nutrient and metals removal
	Extended detention wetland	❍	❍	●	
	Pond/wetland system	❍	❍	●	
Infiltration Practices	Infiltration trench	●	●	●	Frequent sediment/debris removal required for proper performance
	Infiltration basin	●	●	●	
Filtering Practices	Surface sand filter	●	●	●	Periodic removal and replacement of media is required
	Underground sand filter	●	●	●	
	Perimeter sand filter	●	●	●	
	Bioretention	●	●	●	
Water Quality Swales	Dry Swale	❍	❍	❍	Sediment removal may damage swale
	Wet Swale	❍	❍	❍	

Notes: ● Significant ◍ Moderately Significant ❍ Least Significant

Source: Adapted from Watershed Management Institute (WMI), 1997.

rain events and periods of snowmelt. Some of these potential impacts are:

Pipe Freezing: Most treatment practices, with the exception of vegetative filter strips, rely on some form of inlet piping, and may also have an outlet or underdrain pipe. Frozen pipes can crack due to ice expansion, creating a maintenance or replacement burden. In addition, pipe freezing reduces the hydraulic capacity of the system, thereby limiting pollutant removal and creating the potential for flooding (Center for Watershed Protection, 1997).

Ice Formation on the Permanent Pool: Ice cover on the permanent pool causes two problems. First, the treatment pool's volume is reduced. Second, since the permanent pool is frozen, it acts as an impermeable surface. Runoff entering an ice-covered pond can follow two possible routes, neither of which provides sufficient pollutant removal. In the first, runoff is forced under the ice, causing scouring of bottom sediments. In the second, runoff flows over the top of the ice, receiving little or no treatment. Sediment that settles on top of the ice can easily be resuspended by subsequent runoff events (Center for Watershed Protection, 1997).

Reduced Biological Activity: Many stormwater treatment practices rely on biological mechanisms to help reduce pollutants, especially nutrients and organic matter. For example, wetland systems rely on plant uptake of nutrients and the activity of microbes at the soil/root zone interface to break down pollutants. During cold temperatures (below 40°F), photosynthetic and microbial activity is sharply reduced when plants are dormant during the non-growing season, limiting these pollutant removal pathways (Center for Watershed Protection, 1997).

Reduced Soil Infiltration: The rate of infiltration in frozen soils is limited, especially when ice lenses form (Center for Watershed Protection, 1997). This reduced infiltration significantly impacts the operation of infiltration practices and other treatment systems that rely on infiltration of stormwater into the soil.

Table 8-6 summarizes winter operation and cold weather considerations for stormwater treatment practices. Chapter Eleven includes design guidance for mitigating the potential effects of cold weather on treatment practice operation and performance.

8.7 Nuisance Insects and Vectors

Some stormwater treatment practices can provide breeding habitat for mosquitoes, ticks, fleas, and other vectors (organisms that can transmit pathogens that can cause an infectious disease such as West Nile fever, Lyme disease, and St. Louis encephalitis). Mosquitoes are one of the most prevalent nuisance insects, as well as vectors of West Nile fever and Eastern Equine Encephalitis virus, in Connecticut, and therefore are the focus of many municipal control programs.

The approximately 48 species of mosquitoes in Connecticut can be broadly grouped into two categories: those that lay eggs directly on a stagnant water surface ("surface water mosquitoes"), and those that lay eggs on a moist substrate (mud, leaf litter) and hatch at a later date when flooded by rain or tides ("floodwater mosquitoes"). The eggs of floodwater species can lie dormant for several years until conditions are right for hatching. Usually, however, the eggs will survive over winter and hatch with the spring thaw. Eggs of "surface water" mosquitoes do not survive over the winter. The adults survive during the winter in caves, basements, and other similar environments and emerge with warmer weather. The rate of development (from hatching to emergence) is controlled by photoperiod (length of day) and water temperature. In the spring, this may take up to a month and a half. In the summer, it may take as little as 1 to 2 weeks. Generally speaking, relative to stormwater basins and other treatment practices, there is the potential for mosquito breeding if water is allowed to stand or stagnate, in the absence of predators, for more than 7 to 10 days in the summer (Roger Wolfe, Mosquito Management Coordinator, DEP 2003).

When located in residential and urban areas, stormwater treatment practices that hold water for an extended period (longer than 7 to 10 days) have the potential to become new sources of mosquito habitat or aggravate existing mosquito problems. According to national studies conducted by the California Department of Health Services and the California Department of Transportation (1998), stormwater treatment practices that maintain permanent sources of standing water in sumps, basins (wetlands, perimeter sand filters), or wet swales provide habitat for immature mosquitoes and frequently support relatively larger mosquito populations. Catch basins with sumps provide ideal mosquito breeding conditions (particularly species of the genus Culex): stagnant, organically rich water in a shaded and humid environment devoid of predators. In contrast, stormwater treatment practices designed to drain more rapidly (dry swales, filter strips, extended detention structures, and infiltration structures) provide less suitable habitats and rarely harbor mosquitoes. Treatment practices that employ a larger permanent body of open water (i.e., ponds) generally pose lower risk of mosquito breeding since larger open bodies of water are not conducive to mosquito egg laying and, unless extremely polluted, a pond community structure will

Table 8-6 Winter and Cold Weather Operation Criteria

Category	Practice	Pipe Freezing	Ice Formations	Reduced Biological Activity	Reduced Soil Infiltration
Stormwater Ponds	Micropool extended detention pond	●	●	◐	❍
	Wet pond	●	●	◐	❍
	Wet extended detention pond	●	●	◐	❍
	Multiple pond system	●	●	◐	❍
Stormwater Wetlands	Shallow wetland	●	●	●	❍
	Extended detention wetland	●	●	●	❍
	Pond/wetland system	●	●	●	❍
Infiltration Practices	Infiltration trench	❍	❍	❍	●
	Infiltration basin	❍	❍	❍	●
Filtering Practices	Surface sand filter	◐	◐	❍	●
	Underground sand filter	❍	❍	❍	❍
	Perimeter sand filter	◐	◐	❍	❍
	Bioretention	◐	◐	❍	◐
Water Quality Swales	Dry Swale	❍	❍	◐	◐
	Wet Swale	❍	◐	◐	❍

Notes: ● Significant
◐ Moderately Significant
❍ Least Significant

Source: Adapted from Center for Watershed Protection, 1997.

support a natural predator population. Improperly maintained structures can also result in sediment and debris accumulation that can contribute to conditions of prolonged standing water.

Proper siting, design, and maintenance of stormwater treatment practices are important factors in minimizing the potential for these structures to become mosquito-breeding areas. Stormwater ponds, wetlands, and other treatment practices that maintain standing water for a prolonged period should be carefully considered and designed in residential, commercial, and other urban areas where mosquito control is a concern. Key design considerations for mosquito control include:

- *Limiting water retention or draining time to 5 days or less (based on a 7 to 10 day summer breeding period and a factor of safety). Structures designed with sumps or basins that retain water permanently or longer than 5 days should be sealed completely to prevent entry of adult mosquitoes.*
- *Maintaining pond and wetland water quality sufficient to support mosquito-feeding fish and other aquatic predators. Stormwater ponds and wetlands often develop mini-ecosystems where birds, frogs, and other insects feed, many of which are natural predators of mosquitoes and other nuisance insects. Ponds can also be stocked with fish native to Connecticut that feed on mosquito larvae such as banded killfish, golden shiners, and pumpkinseed sunfish. The DEP Inland Fisheries Division should be consulted regarding species selection and permitting requirements. A liberation permit is required to introduce these and other fish into ponds and other water bodies in Connecticut. Other natural predators of mosquitoes such as dragonfly nymphs can also be used.*
- *Maintaining permanent pond water depths in excess of 4 feet to preclude invasive emergent vegetation such as cattails. Dense emergent vegetation provides mosquito larvae with refuge from predators.*
- *Designing ponds to allow for easy dewatering of the basin when necessary.*
- *Providing sufficient slope on basin floors and swales for adequate drainage.*
- *Ensuring sufficient separation distance to the seasonal high groundwater table for infiltration structures.*
- *Sealing potential mosquito entry points in underground stormwater treatment devices (adult female mosquitoes can use openings as small as 1/16 inch to access water for egg laying).*

Chapter Eleven includes additional design guidance to avoid or reduce mosquito-breeding problems for individual treatment practice categories.

8.8 Natural Wetlands and Vernal Pools

Careful consideration should be given to the selection, design, and location of stormwater treatment practices on or near sites with natural wetlands and vernal pools. Conventional stormwater management techniques often have adverse impacts on biodiversity. Wildlife species that migrate seasonally between forested upland habitats and vernal pools (and other small wetlands) are particularly susceptible (Calhoun and Klemens 2002). Populations of turtles, snakes, small mammals, frogs, and salamanders often decline in areas with intensive stormwater management measures. Curb and catch-basin systems, particularly in combination with hydrodynamic separators, can intercept, trap, and kill amphibians and other small animals crossing roads. Stormwater wetlands and ponds that are placed near vernal pools can also threaten pool-breeding amphibian populations. Stormwater ponds and wetlands can serve as "decoy" pools, intercepting amphibians as they migrate in spring to their vernal pool breeding habitats. Amphibians often deposit their eggs in these artificial wetlands. The eggs rarely survive due to sediment and pollutant loads, which are concentrated in these stormwater treatment systems. Fluctuations in water quality, water quantity, and temperature within these decoy wetlands can also cause reproductive failure. Many vernal pool species are extremely sensitive to hydroperiod (duration of flooding). Stormwater management can de-water (or shorten the hydroperiod) vernal pools. This impacts species that require longer hydroperiods such as marbled salamanders. Stormwater management can also increase the hydroperiod of vernal pools, impacting species that require shorter hydroperiods (e.g., fairy shrimp). In addition, constructed wetlands tend to support highly adaptable, widespread, "weedy" species (e.g., bullfrogs or green frogs), which prey upon, or successfully out-compete, vernal pool-breeding amphibians.

Stormwater ponds and wetlands should be located at least 750 feet from a vernal pool and should not be sited between vernal pools or in areas that are primary amphibian overland migration routes, if known (Calhoun and Klemens 2002). Using natural wetlands as stormwater treatment practices is also highly undesirable. Increases in pollutants, sediments, and "flashiness" of the system degrade the wetland and result in a reduction habitat complexity, leading to reductions in biodiversity. In general, stormwater runoff to vernal pools should be maintained at pre-construction levels to avoid increases ordecreases in water levels and hydroperiod. Chapter Eleven contains additional design guidance to avoid impacts to natural wetlands and vernal pools.

Additional Information Sources

U.S. Department of Agriculture (USDA). Natural Resources Conservation Service (NRCS). 2002 (draft). *Soil Suitability for Stormwater Management Practices*. URL: http://www.ct.nrcs.usda.gov. Contact: Kipen Kolesinskas, State Soil Scientist, 344 Merrow Road, Tolland, CT 06084-3917, (860) 871-4047.

References

Calhoun, A.J.K. and M.W. Klemens. 2002. Best development practices: Conserving pool-breeding amphibians in residential and commercial developments in the northeastern United States. MCA Technical Paper No. 5, Metropolitan Conservation Alliance, Wildlife Conservation Society, Bronx, New York.

Center for Watershed Protection (CWP). 1997. *Stormwater BMP Design Supplement for Cold Climates*. Ellicot City, Maryland.

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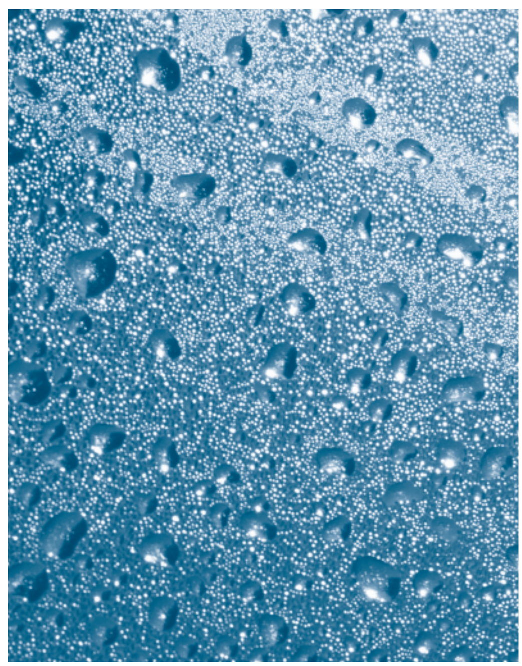
U.S. Environmental Protection Agency (EPA). 1993. *Handbook of Urban Runoff Pollution Prevention and Control Planning*. EPA 625-R-93-004. Washington, D.C.

Winer, R. 2000. *National Pollutant Removal Database for Stormwater Treatment Practices, 2nd Edition*. Center for Watershed Protection. Ellicott City, Maryland.

Chapter 9
Developing a Site Stormwater Management Plan



Volume II: Design

Chapter 9

Developing a Site Stormwater Management Plan

9.1 Plan Development

Stormwater management plans should be developed for all new and redevelopment projects, including phased developments, that meet any of the following criteria:

- *Any development resulting in the disturbance of greater than or equal to one acre of land*
- *Residential development consisting of 5 or more dwelling units*
- *Residential development consisting of fewer than 5 dwelling units involving construction of a new road or reconstruction of an existing road*
- *Residential development consisting of fewer than 5 dwelling units where imperviousness of the site after construction exceeds 30 percent*
- *Stormwater discharge to wetlands/watercourses*
- *New stormwater discharges located less than 500 feet from tidal wetlands*
- *Land uses or facilities with potential for higher pollutant loadings (see Chapter Seven)*
- *Industrial and commercial development projects which result in 10,000 sq. ft. or greater of impervious surface. (Industrial and commercial activities requiring authorization under the DEP* General Permit for the Discharge of Stormwater Associated with Industrial Activity or General Permit for the Discharge of Stormwater Associated with Commercial Activity *have specific Stormwater Management Plan requirements which focus on source controls and pollution prevention.)*
- *New highway, road, and street construction*
- *Modifications to existing storm drainage systems*

These types of projects are also subject to the hydrologic sizing criteria described in Chapter Seven of this Manual.

While this Manual describes the selection and design of a wide range of stormwater treatment practices, it is important that the designer effectively communicates their rationale, design, and maintenance requirements to several audiences including the facility owner, regulatory reviewers, and maintenance personnel. This is critical so that all parties fully understand the need for and the future operation of the treatment practices, and so that the selection of the specified practice is appropriate.

A site stormwater management plan describes the potential water quality and quantity impacts associated with a development project both during and after construction. A stormwater management plan also identifies selected source controls and treatment practices to address those potential impacts, the engineering design of the treatment practices, and maintenance requirements for proper performance of the selected practices.

9.2 Plan Content

A stormwater management plan should include source controls for potential sources of stormwater runoff pollution and treatment controls for stormwater discharges. In addition, any supporting documentation, including calculations, engineering details, or reports, should be provided to illustrate the proposed development's compliance with applicable federal, state, and local regulations, and the design guidelines of this Manual. Professionals (engineers, surveyors, landscape architects, etc.) must affix their seal and dated signature to all plans and documents prepared by them or under their direct supervision.

The major elements of a stormwater management plan include:

- *Applicant/Site Information*
- *Project Narrative*
- *Calculations*

- *Design Drawings and Specifications*
- *Construction Erosion and Sedimentation Controls*
- *Supporting Documents and Studies*
- *Other Required Permits*
- *Operation and Maintenance*

Each of these elements is described further in the following sections. **Appendix D** contains a checklist that can be used in preparing or reviewing a site stormwater management plan.

9.2.1 Applicant/Site Information

The stormwater management plan should include the following information to clearly identify the applicant and site of the proposed activity:

- *Applicant name, legal address, and telephone/fax numbers*
- *Common address and legal description of the proposed site*
- *Site location or locus map*

9.2.2 Project Narrative

Projects that require a stormwater management plan must include documentation that adequately describes the proposed improvements or alterations to the site. In particular, it is necessary to describe any alterations to surface waters, including wetlands and waterways, removal of vegetation, and earth moving operations. The project scope and objective must identify, in summary, the potential water quality impacts to receiving waters during construction and the post-construction water quality and quantity impacts that may occur as a result of the intended use(s) of the property.

In describing the project, alternative designs or construction methods should be evaluated to address the goal of impact minimization through the use of site design practices such as providing "green" parking areas, and preserving natural buffers or open spaces. The purpose of evaluating project alternatives is to achieve a final design that allows an appropriate, legal use of the property while minimizing impacts to surface water quality caused by stormwater runoff.

The project narrative should consist of:

Project Description and Purpose: Provide a general description of the project in adequate detail such that reviewers will have a sense of the proposed project and potential impacts. This section should describe existing and proposed conditions, including:

- *Natural and manmade features at the site including, at a minimum, wetlands, watercourses, floodplains, and development (roads, buildings, and other structures)*
- *Site topography, drainage patterns, flow paths, and ground cover*
- *Impervious area and runoff coefficient*
- *Site soils as defined by USDA soil surveys including soil names, map unit, erodibility, permeability, depth, texture, and soil structure*
- *Stormwater discharges, including the quality of any existing or proposed stormwater discharges from the site and known sources of pollutants and sediment loadings*
- *Critical areas, buffers, and setbacks established by the local, state, and federal regulatory authorities*
- *Water quality classification of on-site and adjacent water bodies and identification of any on-site or adjacent water bodies included on the Connecticut 303(d) list of impaired waters*

Potential Stormwater Impacts: Describe the project's potential for stormwater impacts affecting water quality, peak flow, and groundwater recharge. The elements that should be included in this section are:

- *Description of all potential pollution sources such as erosive soils, steep slopes, vehicle fueling, vehicle washing, etc.*
- *Identification of the types of anticipated stormwater pollutants and the relative or calculated load of each pollutant*
- *A summary of calculated pre- and post-development peak flows*
- *A summary of calculated pre- and post-development groundwater recharge*

Critical On-site Resources: Describe and identify the locations of on-site resources that could potentially be impacted by stormwater runoff. These resources may include:

- *Wells*
- *Aquifers*
- *Wetlands*
- *Streams*
- *Ponds*
- *Public drinking water supplies*

Critical Off-site Resources: Describe and identify the locations of off-site resources (typically downstream of the site) that could potentially be impacted by stormwater runoff. These resources may include:

- *Neighboring land uses*
- *Wells*
- *Aquifers*
- *Wetlands*
- *Streams*
- *Ponds*
- *Public drinking water supplies*

Proposed Stormwater Management Practices: Describe the proposed stormwater management practices and why they were selected for the project. Stormwater management practices that should be described in this section are:

- *Source controls and pollution prevention*
- *Alternative site planning and design*
- *Stormwater treatment practices*
- *Flood control and peak runoff attenuation management practices*

Site Plan: Include a site plan showing, at a minimum, the following existing and proposed features:

- *Topography, drainage patterns, drainage boundaries, and flow paths*
- *Locations of stormwater discharges*
- *Perennial and intermittent streams*
- *Soil types*
- *Proposed borehole investigations*
- *Vegetation and proposed limits of clearing and disturbance*
- *Resource protection areas such as wetlands, lakes, ponds, and other setbacks (stream buffers, drinking water well setbacks, septic setbacks, etc.)*
- *Roads, buildings, and other structures*
- *Utilities and easements*
- *Temporary and permanent conveyance systems (grass channels, swales, ditches, storm drains, etc.) including grades, dimensions, and direction of flow*
- *Location of floodplain and floodway limits and relationship of site to upstream and downstream properties and drainage systems*
- *Location, size, maintenance access, and limits of disturbance of proposed structural stormwater management practices (treatment practices, flood control facilities, stormwater diversion structures, etc.)*
- *Final landscaping plans for structural stormwater management practices and site revegetation*
- *Locations of source controls*

Construction Schedule: Describe the anticipated construction schedule, including the construction sequence and any proposed phasing of the project.

9.2.3 Calculations

The stormwater management plan should include calculations to demonstrate that the proposed project satisfies the stormwater management objectives and treatment practice sizing criteria described in Chapter Seven of this Manual.

Pollutant Reduction

Water Quality Volume (WQV): Calculate the design water quality volume (WQV) to be treated by the proposed stormwater treatment practices using the procedures described in Chapter Seven. Design calculations should demonstrate that the proposed stormwater treatment practices meet the required WQV, detention time, and other practice-specific design criteria as described in this Manual.

Water Quality Flow (WQF): Calculate the design water quality flow (WQF), which is the peak flow rate associated with the WQV. The WQF is used to size flow rate-based treatment practices (i.e., manufactured treatment systems such as catch basin inserts, media filters, and hydrodynamic structures), grass drainage channels, and flow diversion structures for off-line treatment practices. The WQF should be calculated using the procedures described in **Appendix B**. The peak flow rates associated with larger design storms should also be evaluated to ensure that stormwater treatment practices could safely convey large storm events while providing the minimum rates of pollutant removal established in this Manual.

Pollutant Loads: At the discretion of the review authority, estimate pollutant loads found in pre- and post-development runoff. One method to determine stormwater pollutant loads for urbanized areas is the Simple Method developed by Schueler (Metropolitan Washington Council of Governments, 1987). This method can be used to estimate stormwater pollutant loads for different land uses, but does not provide an estimate of the base flow pollutant load. However, the Simple Method may be used to calculate the pollutant load associated with storm events.

Groundwater Recharge

Groundwater Recharge Volume (GRV): Calculate the required groundwater recharge volume to maintain pre-development annual groundwater recharge on the site after the site is developed. The GRV should be calculated using the procedures described in Chapter Seven. The GRV calculation should include the average annual groundwater recharge (i.e., stormwater infiltration) provided by the proposed stormwater management practices.

Runoff Capture

Runoff Capture Volume (RCV): For new stormwater discharges located less than 500 feet from brackish and tidal wetlands, which are not fresh-tidal wetlands, calculate the volume of runoff generated by the first inch of rainfall. The design calculations should demonstrate how the proposed stormwater management system would retain or infiltrate this runoff capture volume (RCV). The RCV should be calculated based on the procedures described in Chapter Seven.

Peak Flow Control (Stormwater Quantity)

For new development projects, calculations should be provided to demonstrate that post-development peak flows do not exceed pre-development peak flows for a range of design storms. For redevelopment projects, the bank condition and sensitivity of receiving waters may justify a reduction in peak flows and runoff volume from the site. Achieving a reduction in runoff from a redevelopment project may often be feasible with proper planning and implementation of detention or infiltration practices.

A number of methods and models are available to calculate peak stormwater discharge rates, and the designer must determine the most appropriate method for the project. The following information must be submitted with all stormwater management plans:

Hydrologic and Hydraulic Design Calculations: Calculate the pre-development and post-development peak runoff rates, volumes, and velocities at the site limits. The calculations shall be based on the following 24-hour duration design storm events to satisfy the sizing criteria described in Chapter Seven:

- ❍ *Stream Channel Protection: 2-year frequency ("over-control" of 2-year storm)*
- ❍ *Conveyance Protection: 10-year frequency*
- ❍ *Peak Runoff Attenuation: 10-year, 25-year, and 100-year frequency (and other design storms required by the local review authority)*
- ❍ *Emergency Outlet Sizing: safely pass the 100-year frequency or larger storm*

Provide the following information for each of the above design storms for pre-development and post-development conditions:

- ❍ *Description of the design storm frequency, intensity, and duration*
- ❍ *Watershed map with locations of design points and watershed area (acres) for runoff calculations*
- ❍ *Time of concentration (and associated flow paths)*
- ❍ *Imperviousness of the entire site and each watershed area*
- ❍ *NRCS runoff curve numbers or volumetric runoff coefficients*
- ❍ *Peak runoff rates, volumes, and velocities for each watershed area*
- ❍ *Hydrograph routing calculations*
- ❍ *Culvert capacities*
- ❍ *Infiltration rates, where applicable*
- ❍ *Dam breach analysis, where applicable*
- ❍ *Documentation of sources for all computation methods and field test results*

Downstream Analysis: Improperly placed or sized detention may adversely affect downstream areas by delaying the timing of the peak flows from the site. Delayed peaks can coincide with the upstream peak flow that naturally occurs later as the discharge travels from the upper portions of the watershed. If the site is in the middle to lower third of a watershed and detention is proposed, provide calculations of existing and proposed discharges at any critical downstream points using hydrograph analysis. Critical downstream points may be currently flooded properties or roadways, for example. Routing calculations should proceed downstream to a confluence point where the site drainage area represents 10 percent of the total drainage area (i.e., the "10 percent rule"). The downstream analysis should be performed using the methods described in Chapter Seven.

Drainage Systems and Structures: Provide design calculations for existing and proposed drainage systems and structures at the site. Based on the design storm for those structures, a hydrograph analysis should be used to analyze the storage and discharge for detention structures. Drainage system components should be designed according to the standards outlined in this Manual, as well as other applicable local standards or requirements.

9.2.4 Design Drawings and Specifications

Design drawings and specifications must be prepared by a professional engineer licensed to practice in the State of Connecticut. The format of site plans and drawings should conform to the following:

- ❍ *Drawings should be no larger than 24" x 36" and no smaller than 8-1/2" x 11".*
- ❍ *Plans and documents should not be pieced together or submitted with handwritten markings. Blue line prints or photocopies of original plans are acceptable.*
- ❍ *A scale should be used that adequately presents the detail of the proposed improvements for the project. A maximum scale of 1" = 40' is recommended, however larger scales up to 1" = 100' may be used to represent overall site development plans or for conceptual plans. Profiles and cross-sections should be prepared at a maximum scale of 1" = 4' vertical and 1"=40' horizontal.*
- ❍ *Design details including cross-sections, elevation views, and profiles as necessary to allow the proper depiction of the proposed controls for review and permitting and ultimately to allow the proper construction of these controls.*
- ❍ *Specifications, which clearly indicate the materials of construction, the specific stormwater control product designations (if applicable), the methods of installation, and reference to applicable material and construction standards.*
- ❍ *Plans should contain a title block that includes the project title, location, owner, assessor's map and parcel number of the subject site(s), name of preparer, sheet number, date (with revision date, if applicable), and drawing scale.*
- ❍ *Legend defining all symbols depicted on the plans.*
- ❍ *A cover sheet with a sheet index for plan sets greater than two sheets. Multiple sheets should contain either match lines or provide an overlap of 1" with information on adjoining plan sheets.*
- ❍ *North arrow.*
- ❍ *Property boundary of the entire subject property and depicting the parcels, or portions thereof, of abutting land and roadways within one hundred feet of the property boundary.*
- ❍ *Locus map of the site prepared at a scale of 1" = 1,000' with a north arrow. The map should adequately show the subject site relative to major roads and natural features, if any.*
- ❍ *The seal of a licensed professional should be affixed to all original design plans, calculations, and reports prepared by them or under their direct supervision.*

- *Survey plans should be prepared according to the* Minimum Standards for Surveys and Maps in Connecticut *with the class of survey represented on the plan, and must be stamped by a professional land surveyor. The survey plan should depict topography at contour intervals of two feet, the referenced or assumed elevation datum, two (2) benchmarks on the site within one hundred feet of the proposed construction, the outside limits of disturbances, and any plan references.*

9.2.5 Construction Erosion and Sedimentation Controls

The proposed Erosion and Sedimentation Control Plan should, at a minimum, demonstrate the methods and designs to be utilized during construction and stabilization of the site following completion of construction activity. All proposed erosion and sediment control measures must comply with the *Connecticut Guidelines for Soil Erosion and Sediment Control, DEP Bulletin 34* (Connecticut Council on Soil and Water Conservation and the Connecticut Department of Environmental Protection, 2002). Erosion and sediment control measures must be included on the plans with sufficient detail to facilitate review of the design by regulatory officials, and proper construction of the measures.

9.2.6 Supporting Documents and Studies

Information used in the design of construction and post-construction stormwater controls for the overall site development must be included (or referenced, if appropriate) with reports, plans, or calculations to support the designer's results and conclusion. Pertinent information may include:

- *Soil maps, borings/test pits*
- *Infiltration test results*
- *Groundwater impacts for proposed infiltration structures*
- *Reports on wetlands and other surface waters (including available information such as Maximum Contaminant Levels [MCLs], Total Maximum Daily Loads [TMDLs], 303(d) or 305(b) impaired waters listings, etc.)*
- *Water quality impacts to receiving waters*
- *Impacts on biological populations/ecological communities including fish, wildlife (vertebrates and invertebrates), and vegetation*
- *Flood study/calculations*

9.2.7 Other Required Permits

Approval of a stormwater management plan does not relieve a property owner of the need to obtain other permits or approvals from federal, state, and local regulatory agencies. Stormwater regulatory programs in the state of Connecticut are summarized in Chapter One of this Manual. The stormwater management plan should include evidence of acquisition of all applicable federal, state, and local permits or approvals such as copies of DEP permit registration certificates, local approval letters, etc.

Where appropriate, a grading or building permit should not be issued for any parcel or lot unless a stormwater management plan has been approved or waived. If requirements of federal, state, and local officials vary, the most stringent requirements should be followed.

9.2.8 Operation and Maintenance

Stormwater management plans should describe the procedures, including routine and non-routine maintenance, that are necessary to maintain treatment practices, including vegetation, in good and effective operating conditions. Chapter Eleven of this Manual contains operation and maintenance guidelines and recommendations for individual stormwater treatment practices. Operation and maintenance elements that should be included in the stormwater management plan include:

- *Detailed inspection and maintenance requirements/tasks*
- *Inspection and maintenance schedules*
- *Parties legally responsible for maintenance (name, address, and telephone number)*
- *Provisions for financing of operation and maintenance activities*
- *As-built plans of completed structures*
- *Letter of compliance from the designer*
- *Post-construction documentation to demonstrate compliance with maintenance activities*

References

Connecticut Council on Soil and Water Conservation and the Connecticut Department of Environmental Protection. 2002. *2002 Connecticut Guidelines for Soil Erosion and Sediment Control, DEP Bulletin 34.*

Connecticut Department of Environmental Protection (DEP). 1995. *General Permit for Stormwater Associated with Commercial Activities.*

Connecticut Department of Environmental Protection (DEP). 1997. *General Permit for Stormwater Associated with Industrial Activities.*

Connecticut Department of Environmental Protection (DEP). 2000. *General Permit for the Discharge of Stormwater and Dewatering Wastewaters Associated with Construction Activities.* Issuance date October 1, 1997, modified December 20, 2000.

Schueler, T.R. 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs.* Metropolitan Washington Council of Governments. Washington, D.C.

Chapter 10
Stormwater Retrofits

Volume II: Design

Chapter 10 Stormwater Retrofits

10.1 Introduction

Existing development can be modified to incorporate source controls and structural stormwater treatment practices. Such modifications are commonly referred to as stormwater retrofits. This chapter describes opportunities and techniques for retrofitting existing, developed sites to improve or enhance water quality mitigation functions. This chapter also identifies the conditions for which stormwater retrofits are appropriate, as well as the potential benefits and effectiveness of stormwater retrofits.

10.2 Objectives and Benefits of Stormwater Retrofits

The objective of stormwater retrofitting is to remedy problems associated with, and improve water quality mitigation functions of, older, poorly designed or poorly maintained stormwater management systems. In Connecticut prior to the 1970s, site drainage design did not require stormwater detention for controlling post-development peak flows. As a result, drainage, flooding, and erosion problems are common in many older developed areas of the state. Furthermore, a majority of the stormwater detention facilities throughout the state have been designed to control peak flows, without regard for water quality mitigation. Therefore, many existing stormwater detention basins provide only minimal water quality benefit.

Incorporating stormwater retrofits into existing developed sites or into redevelopment projects can reduce the adverse impacts of uncontrolled stormwater runoff. This can be accomplished through reduction in unnecessary impervious cover, incorporation of small-scale Low Impact Development (LID) management practices, and construction of new or improved structural stormwater treatment practices. One of the primary benefits of stormwater retrofits is the opportunity to combine stormwater quantity and quality controls. Stormwater retrofits can also remedy local nuisance conditions and maintenance problems in older areas, and improve the appearance of existing facilities through landscape amenities and additional vegetation.

10.3 When is Retrofitting Appropriate?

Site constraints commonly encountered in existing, developed areas can limit the type of stormwater retrofits that are possible for a site and their overall effectiveness. Retrofit of an existing stormwater management facility according to the design standards contained in Chapter Eleven of this Manual may not be possible due to site-specific factors such as the location of existing utilities, buildings, wetlands, maintenance access, and adjacent land uses. **Table 10-1** lists site-specific factors to consider in determining the appropriateness of stormwater retrofits for a particular site.

Retrofitted facilities may not be as effective in reducing pollutant loads as newly designed and installed facilities. However, in most cases, some improvements in stormwater quantity and quality control are possible, especially if a new use is planned for an existing development or an existing storm drainage system is upgraded or expanded. Incorporation of a number of small-scale LID management practices or a treatment train approach may be necessary to achieve the desired level of effectiveness. It should also be recognized that stormwater quantity frequently creates the most severe impacts to receiving waters and wetlands as a result of channel erosion (Claytor, Center for Watershed Protection, 2000). Therefore, stormwater quantity control functions that existing stormwater management facilities provide should not be significantly compromised in exchange for pollutant removal effectiveness.

10.4 Stormwater Retrofit Options

Stormwater retrofit options include many of the same source control and stormwater treatment practices for new developments that are described in other chapters of this Manual. Common stormwater retrofit applications for existing development and redevelopment projects include:

- *Stormwater drainage system retrofits*
- *Stormwater management facility retrofits*

Table 10-1 Site Considerations for Determining the Appropriateness of Stormwater Retrofits

Factor	Consideration
Retrofit Purpose	What are the primary and secondary (if any) purposes of the retrofit project? Are the retrofits designed primarily for stormwater quantity control, quality control, or a combination of both?
Construction/Maintenance Access	Does the site have adequate construction and maintenance access and sufficient construction staging area? Are maintenance responsibilities for the retrofits clearly defined?
Subsurface Conditions	Are the subsurface conditions at the site (soil permeability and depth to groundwater/bedrock) consistent with the proposed retrofit regarding subsurface infiltration capacity and constructability?
Utilities	Do the locations of existing utilities present conflicts with the proposed retrofits or require relocation or design modifications?
Conflicting Land Uses	Are the retrofits compatible with adjacent land uses of nearby properties?
Wetlands, Sensitive Water Bodies, and Vegetation	How do the retrofits affect adjacent or downgradient wetlands, sensitive receiving waters, and vegetation? Do the retrofits minimize or mitigate impacts where possible?
Complementary Restoration Projects	Are there opportunities to combine stormwater retrofits with complementary projects such as stream stabilization, habitat restoration, or wetland restoration/mitigation?
Permits and Approvals	Which local, state, and federal regulatory agencies have jurisdiction over the proposed retrofit project, and can regulatory approvals be obtained for the retrofits?
Public Safety	Does the retrofit increase the risk to public health and safety?
Cost	What are the capital and long-term maintenance costs associated with the stormwater retrofits? Are the retrofits cost-effective in terms of anticipated benefits?

Source: Adapted from Claytor, Center for Watershed Protection, 2000.

- *New stormwater controls at storm drain outfalls*
- *New stormwater controls for road culverts and rights-of-way*
- *In-stream practices in existing drainage channels*
- *Parking lot stormwater retrofits*
- *Wetland creation and restoration*

Examples of these stormwater retrofits are described in the following sections.

10.4.1 Stormwater Drainage Systems

Existing drainage systems can be modified to improve water quality mitigation and sediment removal functions. These retrofits alone typically provide limited benefits, but are most successful when used in conjunction with other source controls and stormwater treatment practices. Due to their very nature as an integral part of the stormwater collection and conveyance system and inherent solids trapping function, these retrofits typically have high maintenance requirements. Common examples of stormwater drainage system retrofits include:

Deep Sump Catch Basins with Hoods: Older catch basins without sumps can be replaced with catch basins having four to six-foot deep sumps. Sumps provide storage volume for coarse sediments, provided that accumulated sediment is removed on a regular basis. Hooded outlets, which are covers over the catch basin outlets that extend below the standing water, can also be used to trap litter and other floatable materials. A recent study conducted in New York City demonstrated that catch basins equipped with hoods increase the capture of floatables by 70 to 80 percent over catch basins without hoods and greatly extend the cleaning interval without degraded capture performance (Pitt, 1999 in NRDC, 1999).

Catch Basin Inserts and Storm Drain Structures: As discussed in Chapter Six, a number of manufactured devices have been developed that can be inserted into storm drains or catch basins to capture sediment and other pollutants directly beneath the grate. These products typically utilize filter media or vortex action for removal of solids from incoming stormwater runoff. These devices are ideally suited for developed sites since they fit inside of or replace existing catch basins, or are installed beneath existing parking lots with minimal or no additional space requirements.

10.4.2 Stormwater Management Facilities

Existing stormwater management facilities originally designed for flood control can be modified or reconfigured for water quality mitigation purposes or increased hydrologic benefit. Older detention facilities offer the greatest opportunity for this type of retrofit. Traditional dry detention basins can be modified to become extended detention basins, wet ponds, or stormwater wetlands for enhanced pollutant removal. This is one of the most common and easily implemented retrofits since it typically requires little or no additional land area, utilizes an existing facility for which there is already some resident acceptance of stormwater management, and involves minimal impacts to environmental resources (Claytor, Center for Watershed Protection, 2000).

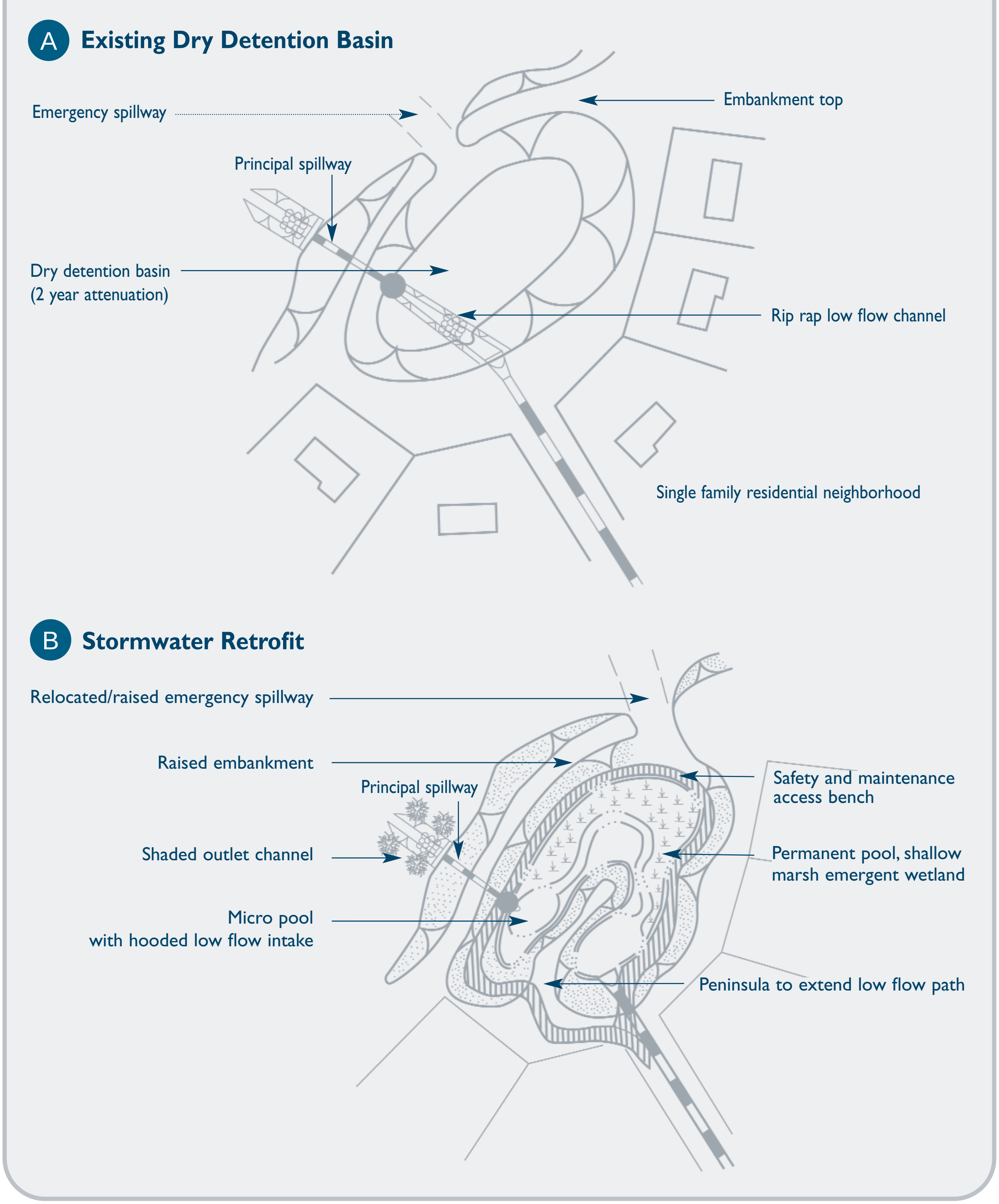
Specific modifications to existing detention basins for improved water quality mitigation are summarized in **Table 10-2.** Stormwater detention basin retrofits should include an evaluation of the hydraulic characteristics and storage capacity of the basin to determine whether available storage exists for additional water quality treatment. A typical retrofit of an existing detention basin is shown in **Figure 10-1**.

Table 10-2
Detention Basin Retrofits for Improved Water Quality Mitigation

Excavate the basin bottom to create more permanent pool storage	Eliminate low-flow bypasses
Raise the basin embankment to obtain additional storage for extended detention	Incorporate stilling basins at inlets and outlets and sediment forebays at basin inlets
Modify the outfall structure to create a two-stage release to better control small storms while not significantly compromising flood control detention for large storms	Regrade the basin bottom to create a wetland area near the basin outlet or revegetate parts of the basin bottom with wetland vegetation to enhance pollutant removal, reduce mowing, and improve aesthetics
Increase the flow path from inflow to outflow and eliminate short-circuiting by using baffles, earthen berms, or micro-pond topography to increase residence time of water in the pond and improve settling of solids	Create a wetland shelf along the perimeter of a wet basin to improve shoreline stabilization, enhance pollutant filtering, and enhance aesthetic and habitat functions
Replace paved low-flow channels with meandering vegetated swales	Create a low maintenance "no-mow" wildflower ecosystem in the drier portions of the basin
Provide a high flow bypass to avoid resuspension of captured sediment/pollutants during high flows	

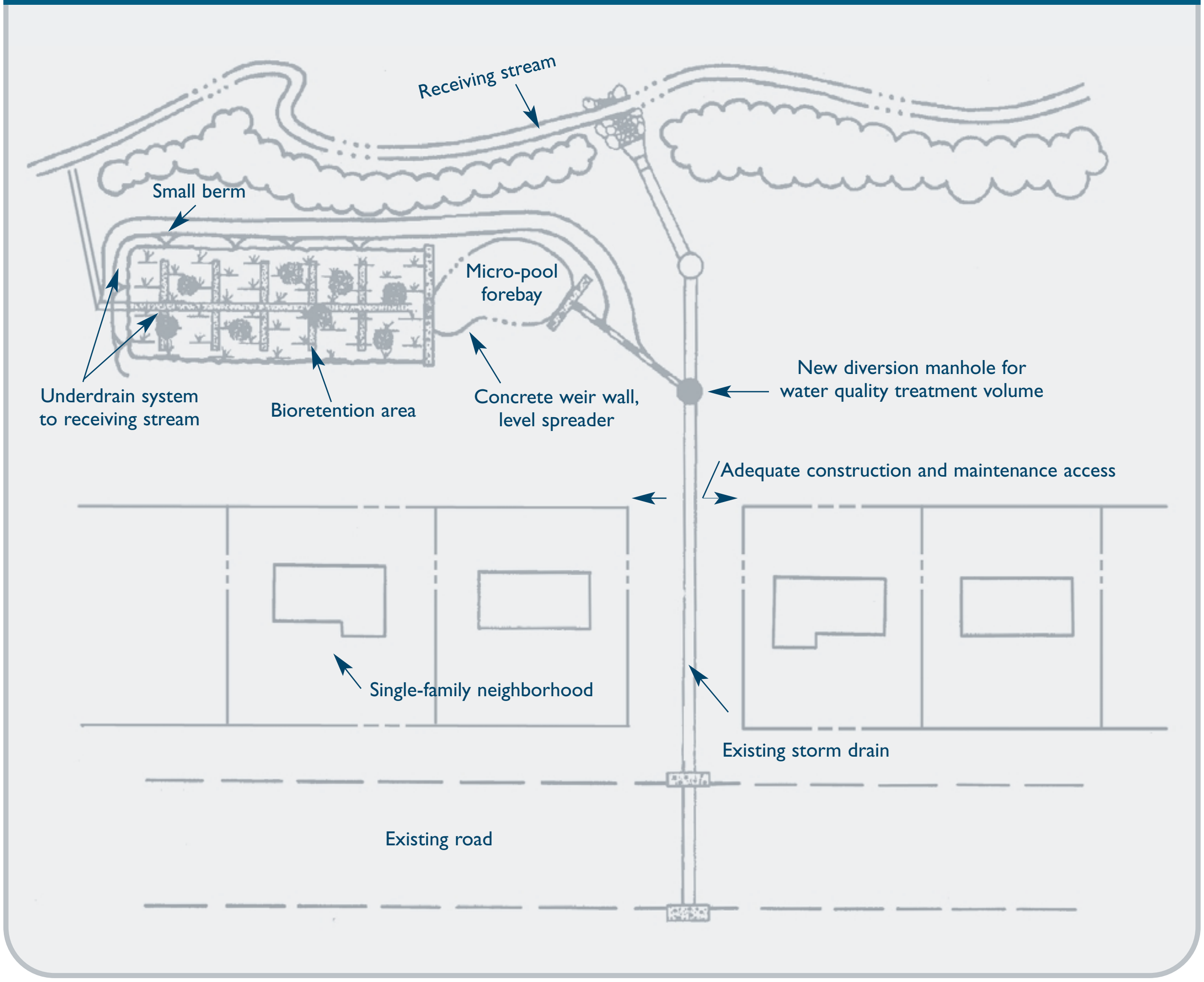
Source: Adapted from Claytor, Center for Watershed Protection, 2000; Pennsylvania Association of Conservation Districts et al., 1998; and NJDEP, 2000.

Figure 10-1 Stormwater Retrofit of an Existing Dry Detention Basin



Source: Claytor, Center for Watershed Protection, 2000.

Figure 10-2 Typical Stormwater Retrofit at Existing Storm Drain Outfall



Source: Claytor, Center for Watershed Protection, 2000.

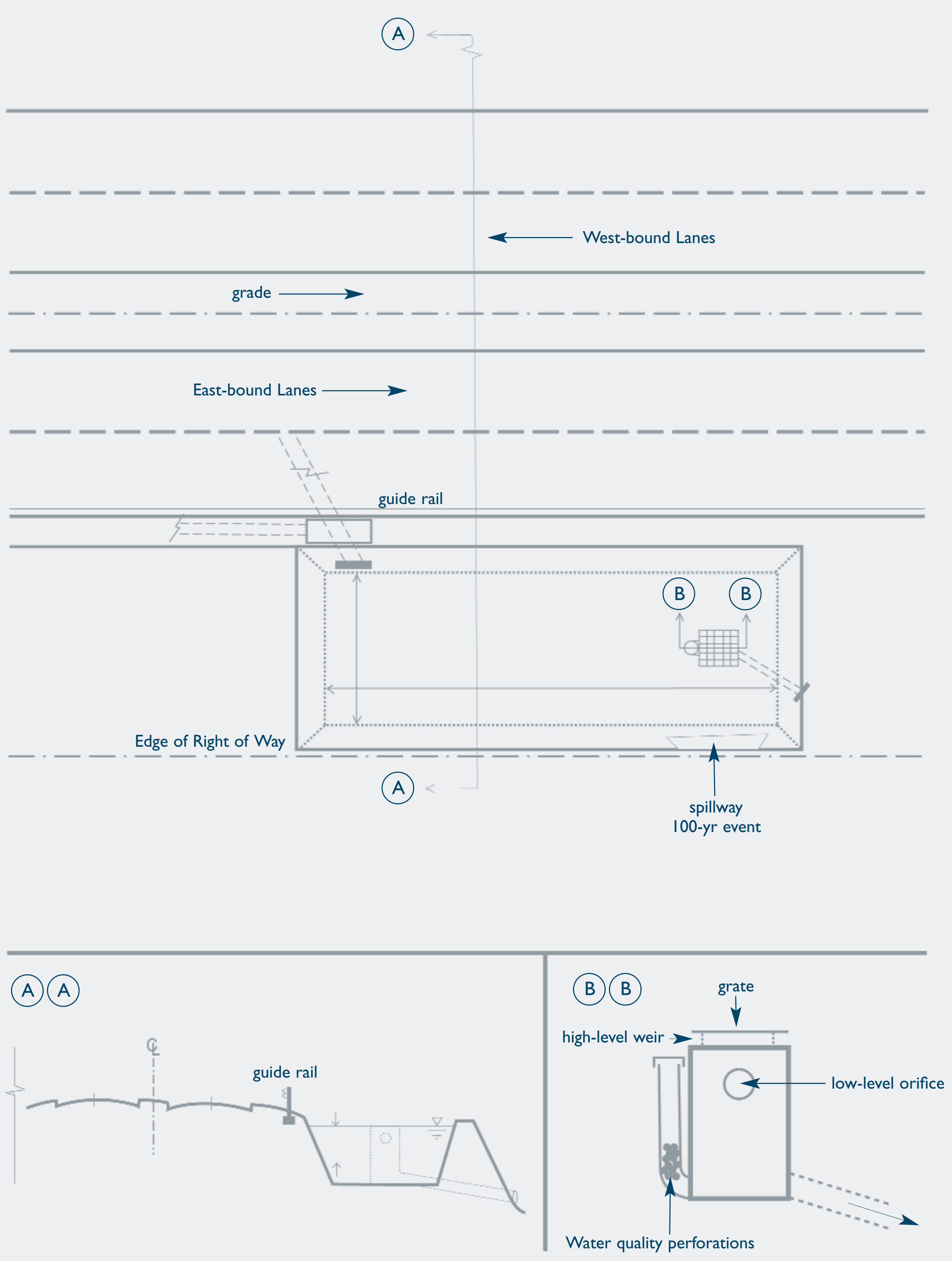
10.4.3 Storm Drain Outfalls

New stormwater treatment practices can be constructed at the outfalls of existing drainage systems. The new stormwater treatment practices are commonly designed as off-line devices to treat the water quality volume and bypass larger storms. Water quality swales, bioretention, sand filters, constructed wetlands, and wet ponds are commonly used for this type of retrofit, although most stormwater treatment practices can be used for this type of retrofit given enough space for construction and maintenance. **Figure 10-2** shows a schematic of an existing outfall retrofitted with an off-line bioretention area. Manufactured, underground treatment devices such as those described in Chapter Six are also commonly installed as off-line retrofits at or upgradient of stormwater outfalls. Velocity dissipation devices such as plunge pools and level spreaders can also be incorporated into the retrofit design.

10.4.4 Highway Rights-of-Way

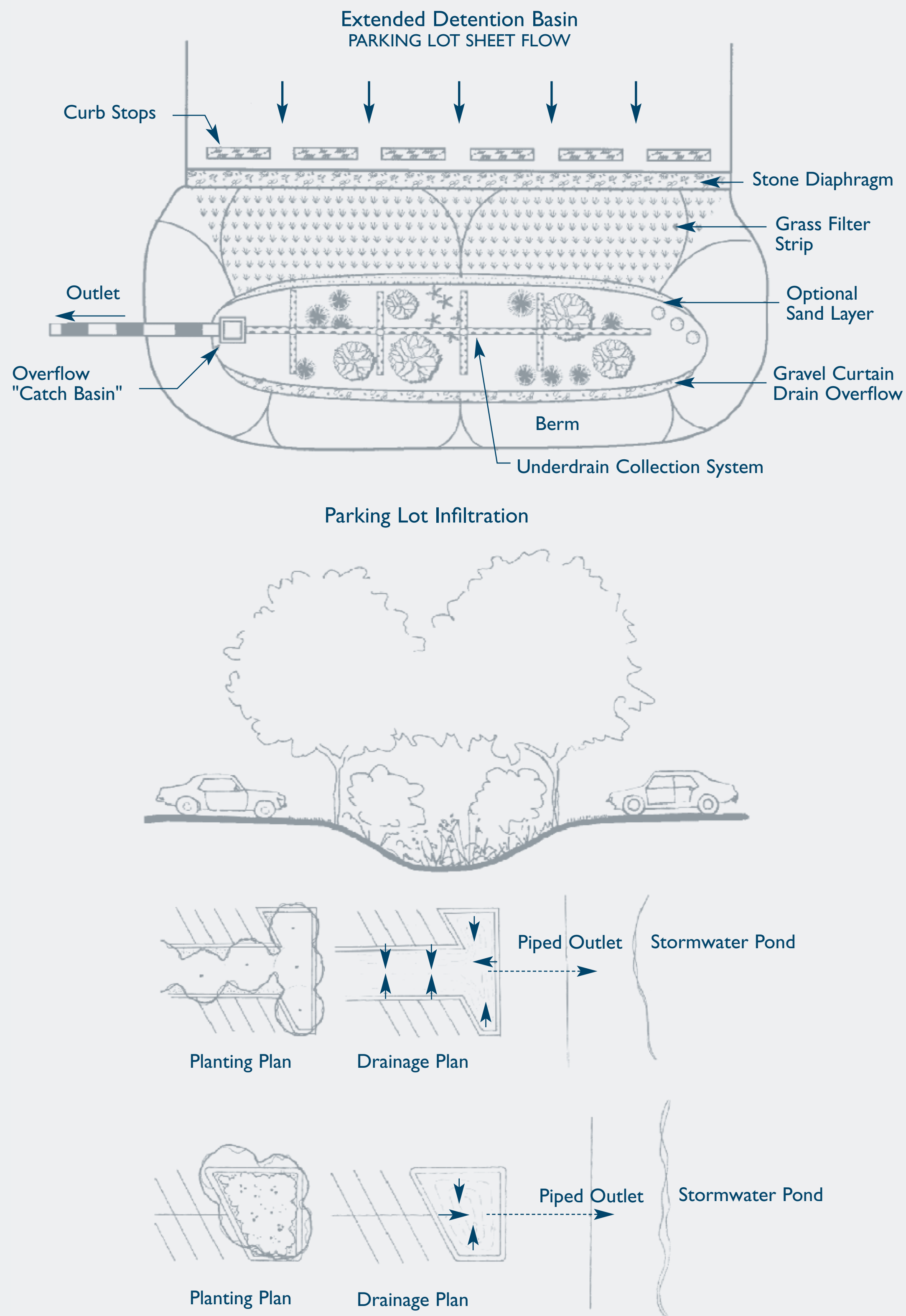
Open spaces associated with highway rights-of-way such as medians, shoulders, and cloverleaf areas also present opportunities to incorporate new stormwater treatment practices. Common treatment practices used in these types of retrofits include vegetated swales, bioretention, constructed wetlands, and extended detention ponds. Traffic, safety, and maintenance access are important considerations for determining appropriate locations for highway right-of-way retrofits. **Figure 10-3** shows a schematic of an extended detention basin incorporated into an existing highway right-of-way.

Figure 10-3 Stormwater Retrofit in Highway Right-of-Way



Source: Adapted from Federal Highway Administration, 1996.

Figure 10-4 Parking Lot Stormwater Retrofit Schematics



Source: Metropolitan Council, 2001 (Adapted from VBWD, 2000) and NYDEC, 2001

10.4.5 Parking Lots

Parking lots can be ideal candidates for a wide range of stormwater retrofits. Potentially applicable retrofits include site planning techniques and small-scale management measures to reduce impervious coverage and promote increased infiltration (see Chapter Four), as well as a variety of larger, end-of-pipe treatment practices. Redevelopment of older commercial properties, which were often designed with oversized parking lots and almost 100 percent impervious coverage, is one of the most common and environmentally beneficial opportunities for parking lot stormwater retrofits.

Alternative site design and LID management practices are well suited to existing developed areas because most of these practices use a small amount of land and are easily integrated into existing parking areas. Examples of these parking lot stormwater retrofits include:

Incorporating Bioretention Into Parking Lot Islands and Landscaping: Parking lot islands, landscaped areas, and tree planter boxes can be converted into functional bioretention areas and rain gardens to reduce and treat stormwater runoff.

Removing Curbing and Adding Slotted Curb Stops: Curbs along the edges of parking lots can sometimes be removed or slotted to re-route runoff to vegetated areas, buffer strips, or bioretention facilities. The capacity of existing swales may need to be evaluated and expanded as part of this retrofit option.

Infiltrating Clean Roof Runoff From Buildings: In some instances, building roof drains connected to the stormwater drainage system can be disconnected and re-directed to vegetated areas, buffer strips, bioretention facilities, or infiltration structures (dry wells or infiltration trenches).

Incorporating New Treatment Practices at the Edges of Parking Lots: New stormwater treatment practices such as bioretention, sand filters, and constructed wetlands can often be incorporated at the edges of large parking lots.

Use of Permeable Paving Materials: Existing impermeable pavement in overflow parking or other low-traffic areas can sometimes be replaced with alternative, permeable materials such as modular concrete paving blocks, modular concrete or plastic lattice, or cast-in-place concrete grids. Site-specific factors including traffic volumes, soil permeability, maintenance, sediment loads, and land use must be carefully considered for the successful application of permeable paving materials for new development or retrofit applications.

Figure 10-4 depicts some of the parking lot stormwater retrofits described above.

10.4.6 In-stream Practices in Drainage Channels

Existing (man-made) channelized streams and drainage conveyances such as grass channels can be modified to reduce flow velocities and enhance pollutant removal. Weir walls or riprap check dams placed across a channel create opportunities for ponding, infiltration, and establishment of wetland vegetation upstream of the retrofit (Claytor, Center for Watershed Protection, 2000). In-stream retrofit practices include stream bank stabilization of eroded areas and placement of habitat improvement structures (i.e., flow deflectors, boulders, pools/riffles, and low-flow channels) in impacted natural streams and along stream banks. In-stream retrofits may require evaluation of potential flooding and floodplain impacts resulting from altered channel conveyance, as well as local, state, or federal approval for work in wetlands and watercourses. More comprehensive urban stream and stream corridor restoration practices are beyond the scope of this Manual. Additional sources of information on stream restoration practices are included at the end of this chapter.

10.4.7 Wetland Creation and Restoration

Wetland creation or restoration can partially substitute for lost ecological functions of a destroyed or degraded wetland system in developed areas. Creation or restoration of freshwater or tidal wetlands can improve the pollutant removal, longevity, adaptability, and habitat functions of wetland systems (DEP, 1995). Techniques to improve pollutant removal in created or restored wetlands include:

- *Increasing wetland volume to increase residence time*
- *Increasing the surface area to volume ratio of the wetland*
- *Increasing the flow path through the wetland*
- *Providing energy dissipation and primary sedimentation either prior to the wetland or in a sediment forebay at the wetland inflow locations*
- *Integrating with other treatment practices such as extended detention*

(Schueler et al., 1992) When wetlands are altered through clearing of vegetation, impoundment of water, or dredging, the microhabitats used by many wildlife species are changed or lost. This may result in unsuitable breeding habitat for many amphibians, including vernal pool species. Similarly, created wetlands usually lack the structural diversity, microhabitats, and hydrology to support vernal pool breeding amphibians (Calhoun and Klemens, 2002). Altered and created wetlands often support highly adaptable, widespread, "weedy" species (e.g., bullfrogs or green frogs) that prey upon, or successfully out-compete, vernal pool-breeding amphibians, which reduces or locally eliminates populations of these habitat specialists. Created wetlands that do not have the appropriate habitat often attract breeding amphibians, which serve as "decoy" pools and trap breeding amphibians. Therefore, these wetland creation and restoration techniques should only be implemented with careful consideration of the effects to wetland function and hydrology and in conjunction with applicable local, state, and federal wetland and watercourses regulatory agencies.

Additional Information Sources

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Chapter 11
Stormwater Treatment Practice Design Guidance

Volume II: Design

Chapter 11

Stormwater Treatment Practice Design Guidance

This chapter provides guidance on the design, construction, and maintenance of the stormwater treatment practices contained in this Manual. **Table 11-1** lists the individual primary and secondary stormwater treatment practices that were introduced in Chapter Six and are described further in subsequent sections of this chapter.

Table 11-1
Summary of Stormwater Treatment Practices

Primary (P) Treatment Practice	Secondary (S) Treatment Practice
Stormwater Ponds (P1) ○ Micropool Extended Detention Pond ○ Wet Pond ○ Wet Extended Detention Pond ○ Multiple Pond System ○ Pocket Pond Stormwater Wetlands (P2) ○ Shallow Wetland ○ Extended Detention Wetland ○ Pond/Wetland System Infiltration Practices (P3) ○ Infiltration Trench ○ Infiltration Basin Filtering Practices (P4) ○ Surface Sand Filter ○ Underground Sand Filter ○ Perimeter Sand Filter ○ Organic Filter ○ Bioretention Water Quality Swales (P5) ○ Dry Swale ○ Wet Swale	Conventional Practices ○ Dry Detention Pond (S1) ○ Underground Detention Facilities (S2) ○ Deep Sump Catch Basins (S3) ○ Oil/Particle Separators (S4) ○ Dry Wells (S5) ○ Permeable Pavement (S6) ○ Vegetated Filter Strips/Level Spreaders (S7) ○ Grass Drainage Channels (S8) Innovative/Emerging Technologies ○ Catch Basin Inserts (S9) ○ Hydrodynamic Separators (S10) ○ Media Filters (S11) ○ Underground Infiltration Systems (S12) ○ Alum Injection (S13)

Primary Treatment Practices

This chapter provides the following information for each primary treatment practice:

Description: A brief description of the treatment practice. The stormwater management benefits of the treatment practice (i.e., runoff volume reduction, pollutant reduction, stream channel/conveyance protection, and flood control) and effectiveness for removal of specific categories of pollutants are summarized at the beginning of each description for quick reference and screening.

Design Variations: Descriptions of common design variations for those treatment practices for which multiple designs have been developed.

Advantages: The major beneficial factors or considerations (e.g., environmental, economic, safety) for selecting a specific stormwater treatment practice.

Limitations: The major limitations or drawbacks of a stormwater treatment practice that may preclude its use for a given site.

Siting Considerations: The site conditions required for implementation of a stormwater treatment practice, such as minimum contributing drainage area, subsurface conditions, and minimum setbacks.

Design Criteria: Specific technical requirements and recommendations for designing the major elements of a stormwater treatment practice, including criteria for design variants within each treatment practice category.

Construction: Recommended construction procedures and methods to ensure that a stormwater treatment practice functions as designed.

Inspection and Maintenance: Routine and non-routine operation and maintenance required for the stormwater treatment practice to function properly over time.

Cost Considerations: Approximate capital costs to design, construct, and implement the stormwater treatment practice, as well as approximate annual operation and maintenance costs, where available.

Secondary Treatment Practices

Secondary treatment practices are described in less detail due to their limited applicability for water quality control. The following guidance is provided for these treatment practices:

Description: A brief description and associated stormwater management benefits of the treatment practice.

Reasons for Limited Use: Rationale for why the practice generally does not meet the performance standards required for classification as a primary treatment practice.

Suitable Applications: The conditions or applications for which the practice is typically suitable (i.e., pretreatment, ultra-urban environments, etc.)

Design Considerations: Key factors for siting, designing, and implementing the treatment practice.

Stormwater Ponds

Source: Nonpoint Education for Municipal Officials (NEMO).

Treatment Practice Type

Primary Treatment Practice ●
Secondary Treatment Practice

Stormwater Management Benefits

Pollutant Reduction

Sediment	■
Phosphorus	■
Nitrogen	■
Metals	■
Pathogens	▣
Floatables*	■
Oil and Grease*	■
Dissolved Pollutants	▣

Runoff Volume Reduction

Runoff Capture	■
Groundwater Recharge	□

Stream Channel Protection ■

Peak Flow Control ■

Key: ■ Significant Benefit
▣ Partial Benefit
□ Low or Unknown Benefit

*Only if a skimmer is incorporated

Implementation Requirements

Cost ....Moderate
Maintenance......................Moderate

Description

Stormwater ponds are vegetated ponds that retain a permanent pool of water and are constructed to provide both treatment and attenuation of stormwater flows. This section addresses four types of stormwater ponds:

- *Wet Pond*
- *Micropool Extended Detention Pond*
- *Wet Extended Detention Pond*
- *Multiple Pond System*

Through careful design, stormwater ponds can be effective at removing urban pollutants. Treatment is primarily achieved by the sedimentation process where suspended particles and pollutants settle to the bottom of the pond. Stormwater ponds can also potentially reduce soluble pollutants in stormwater discharges by adsorption to sediment, bacterial decomposition, and the biological processes of aquatic and fringe wetland vegetation.

The key to maximizing the pollutant removal effectiveness of stormwater ponds is maintaining a permanent pool. To achieve this, wet ponds typically require a large contributing watershed with either an impermeable liner or an elevated water table without a liner. The pool typically operates on the instantaneously mixed reservoir principle where incoming water mixes with the existing pool and undergoes treatment through sedimentation and the other processes. When the existing pool is at or near the pond outlet or when the primary flow path through the pond is highly linear, the pond may act as a plug flow system in which incoming water displaces the permanent pool, which is then discharged from the pond. The value provided by this process is that a portion of the "new," polluted runoff is retained as the "old," treated water is discharged from the pond, thereby allowing extended treatment of the water quality volume (WQV). For example, when sized to store the WQV, a pond system will retain all of the water from storms that generate runoff less than or equal to the WQV and result in a significantly increased period of time available for treatment. For storms that generate runoff greater than the WQV, wet ponds still provide a reduced level of treatment through conventional settling and filtration for the additional runoff volume that is conveyed through the pond. The pond volume should be greater than or equal to the WQV to ensure at least one-day retention time within the pond.

When properly designed, the permanent pool reduces the velocity of incoming water to prevent resuspension of particles and promote settling of newly introduced suspended solids. The energy dissipating and treatment properties of the permanent pool are enhanced by aquatic vegetation, which is an essential part of the stormwater pond design. In contrast, dry detention ponds, or dry extended detention ponds that have no permanent pool, are not considered an acceptable option for treating the WQV due to the potential for resuspension of accumulated sediment by incoming storm flows during the early portion of a storm event when the pond is empty.

Several design variations of stormwater ponds exist that can fit a wide range of design conditions. Descriptions of these design variations are provided in the following section.

Design Variations

Wet Ponds: Wet ponds typically consist of two general components - a forebay and a permanent wet pool. The forebay provides pretreatment by capturing coarse sediment particles in order to minimize the need to remove the sediments from the primary wet pool. The wet pool serves as the primary treatment mechanism and where much of the retention capacity exists. Wet ponds can be sized for a wide range of watershed sizes, if adequate space exists. For example, a variation on the conventional wet pond, sometimes referred to as a "pocket pond", is intended to serve relatively small drainage areas (between one and five acres). Because of these smaller drainage areas and the resulting lower hydraulic loads of pocket ponds, outlet structures can be simplified and often do not have safety features such as emergency spillways and low level drains. **Figure 11-P1-1** depicts a typical schematic design of a conventional wet pond, while **Figure 11-P1-2** shows a typical schematic design of a modified wet pond or "pocket pond".

Several adaptations of this basic design have been developed to achieve the specific treatment goals of various watershed or site conditions. These wet pond design variations are described below.

Micropool Extended Detention Pond: Micropool extended detention basins are primarily used for peak runoff control and utilize a smaller permanent pool than conventional wet ponds. While micropool extended detention ponds are not as efficient as wet ponds for the removal of pollutants, they should be considered when a large open pool might be undesirable or unacceptable. Undesirable conditions could include thermal impacts to receiving streams from a large open pool, safety concerns in residential areas, or where maintaining a large open pool of water would be difficult due to a limited drainage area or deep groundwater.

Micropool extended detention ponds are also efficient as a stormwater retrofit to improve the treatment performance of existing detention basins. **Figure 11-P1-3** depicts a typical schematic design of a micropool extended detention pond.

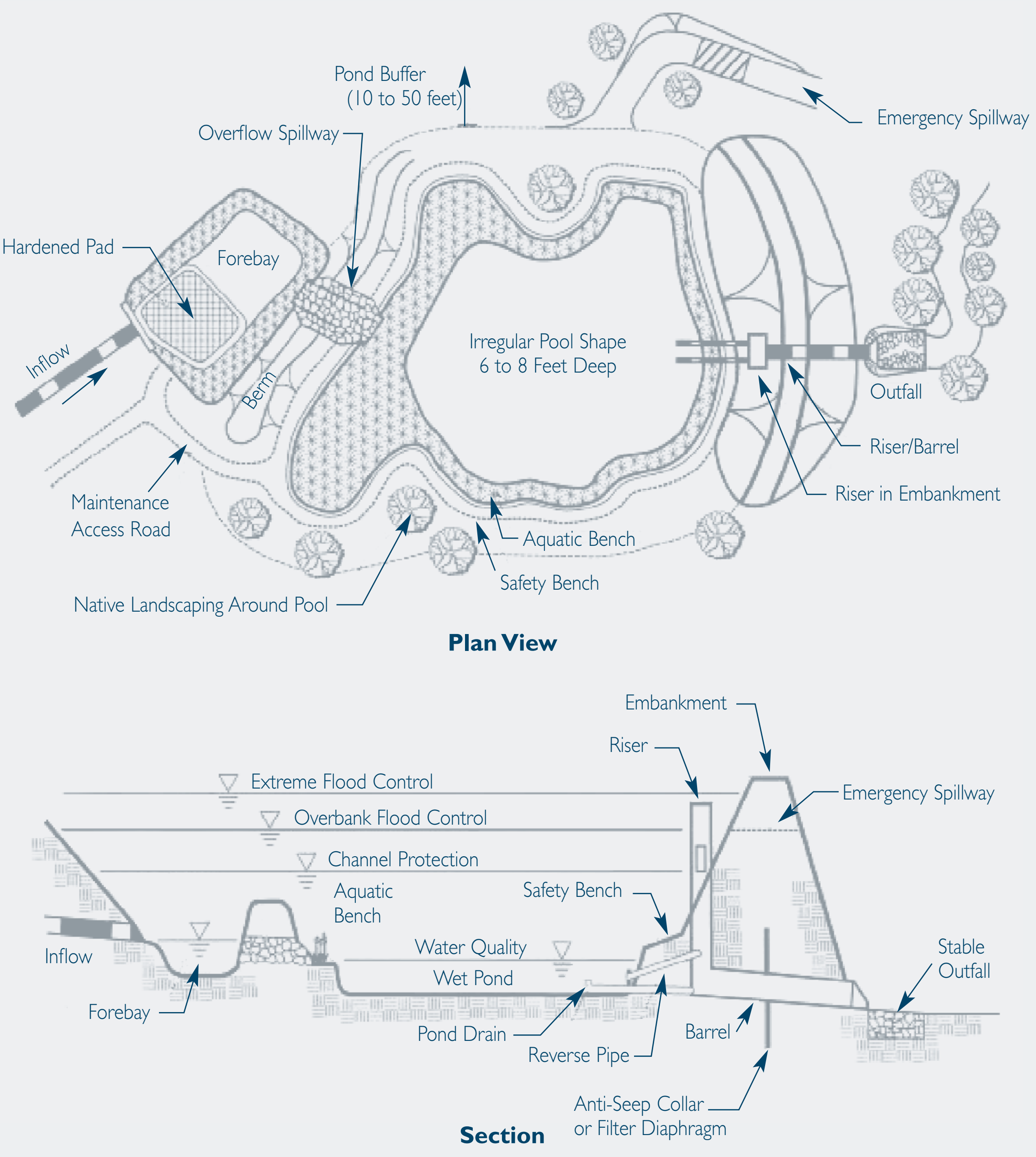
Wet Extended Detention Ponds: These ponds are very similar to wet ponds with the exception that their design is more focused on attenuating peak runoff flows. As a result, more storage volume is committed to managing peak flows as opposed to maximizing the wet pool depth. The configuration of the outfall structure may also differ from typical wet pond designs to provide additional storage volume above the level of the permanent pool. **Figure 11-P1-4** depicts a typical schematic design of a wet extended detention pond.

Multiple Pond System: Multiple pond systems consist of several wet pools that are constructed in a series following a forebay. The advantage of these systems is that they can improve treatment efficiency by better simulating plug flow conditions as compared to a single large wet pool. Also, these systems can reduce overall maintenance needs since more frequent maintenance would be performed within the first pool cells as opposed to the large, primary pool. The disadvantage of these systems is that they typically require more land area to treat the same water quality volume. **Figure 11-P1-5** depicts a typical schematic design of a multiple pond system.

Advantages

- *Can capture/treat both particulate and soluble pollutants. Stormwater ponds are one of the most effective stormwater treatment practices for treating soluble pollutants.*
- *Can provide an aesthetic benefit if open water is desired as part of an overall landscaping plan.*
- *May provide wildlife habitat with appropriate design elements.*
- *Can be adapted to fit a wide range of sites. Design variations allow this control to be utilized for both small and large drainage areas. Pollutant removal mechanisms make stormwater ponds efficient in treatment of pollutants-of-concern from a wide range of land uses.*

Figure 11-P1-1 Wet Pond



Source: Adapted from NYDEC, 2001.

Limitations

- *Unlined ponds that intercept groundwater have potential to impact groundwater quality if dissolved pollutants are present in the runoff.*
- *Lined ponds typically require a minimum drainage area in order to maintain a permanent pool, which may become difficult during extended dry periods.*
- *Require a relatively large land area that is directly proportional to the size of the area draining to it.*
- *May cause thermal impacts to receiving waters and thereby are not recommended to discharge directly to cold water fish habitats.*
- *Require more storage volume (i.e., above permanent pool) to attenuate peak flows.*
- *Potential breeding habitat for mosquitoes, particularly for smaller ponds with stagnant water or isolated pockets of standing water (rather than large open water bodies). Circulating water in the permanent pool may minimize this problem. This may be a more significant problem for lined basins.*
- *Pollutant removal efficiency can be affected in cold climates due to ice formation on the permanent pool and longer particle settling times associated with higher density water during winter months. However, modifications to a pond's design can help maintain the primary pollutant removal mechanism of sedimentation.*
- *Ponds with steep side slopes and/or deep wet pools may present a safety issue to nearby pedestrians.*
- *Stormwater ponds can serve as decoy wetlands, intercepting breeding amphibians moving toward vernal pools. If amphibians deposit their eggs in these artificial ponds/wetlands, they rarely survive due to the sediment and pollutant loads, as well as fluctuations in water quality, quantity, and temperature.*

Siting Considerations

Drainage Area: Stormwater ponds that utilize a liner system should have a contributing drainage area that is adequate to maintain minimum water levels. Typically, minimum contributing watersheds for unlined ponds are twenty-five acres for wet ponds, wet extended detention ponds, and multiple pond systems; ten acres for micropool extended detention ponds; and one to five acres for pocket ponds.

Groundwater: Unlined basins must intersect the groundwater table in order to maintain the desired permanent pool. In this case, the elevations of the basin should be established such that the groundwater elevation is equal to the desired permanent pool elevation. Seasonal variations of groundwater elevations should be considered, which can be very pronounced in low permeability soils.

Land Uses: Land uses will dictate potential pollutants-of-concern and potential safety risks. For those land uses where there is significant potential for soluble pollutants, especially those that are highly susceptible to groundwater transport, the use of a liner is recommended. An impermeable liner may not be required depending on risk of downstream contamination, but a low permeability liner constructed in till soils may be acceptable. With regard to potential safety issues, adjacent residential land uses pose the greatest risks where mosquito breeding and water hazards must be considered.

Baseflow: A small amount of baseflow is desirable to maintain circulation and reduce the potential for low dissolved oxygen levels during late summer. This baseflow can be provided by groundwater infiltrating into either the basin or the collection system above the pond.

Site Slopes: Steep on-site slopes may result in the need for a large embankment to be constructed to provide the desired storage volume, which could require a dam construction permit from the Connecticut DEP. Steep slopes may also present design and construction challenges, and significantly increase the cost of earthwork.

Receiving Waters: The sensitivity of receiving waters should be evaluated to determine whether the effects of the warmer stormwater discharges from the wet pond could be detrimental to cold water fish or other sensitive aquatic species.

Flood Zones: Ponds should not be located in floodways, floodplains, or tidal lands, especially those that require construction of an embankment. Floodwaters could flush out stored pollutants or damage pond embankments.

Natural Wetlands/Vernal Pools: Natural wetlands and vernal pool depressions should not be used, either temporarily or permanently, as a stormwater pond or wetland. Stormwater ponds should be located at least 750 feet from a vernal pool. They should not be sited between vernal pools, or in areas that are known primary amphibian overland migration routes.

Table 11-P1-1 Design Criteria for Stormwater Ponds

Parameter	Design Criteria
Setback requirements[1]	❍ 50 feet from on-site sewage disposal systems ❍ 50 feet from private wells ❍ 10 feet from a property line ❍ 20 feet from any structure ❍ 50 feet from any steep slope (greater than 15%) ❍ 750 feet from a vernal pool
Preferred Shape	Curvilinear
Side Slopes	3:1 maximum or flatter preferred
Length to Width Ratio	3:1 minimum along the flow path between the inlet and outlet; flow length is the length at mid-depth (avg. top width+avg. bottom width)/2
Pretreatment Volume	Forebays are highly recommended for wet ponds and sized to contain 10% of the WQV. For sites with potential for higher pollutant loads (see Chapter Seven), 100% of the WQV must receive pretreatment.
Pond Volume	Minimum pond volume, including pretreatment volume, should be equal to or exceed the WQV.
Drainage Area	Minimum contributing drainage area is 25 acres for wet ponds, 10 acres for extended detention basins, and 1-5 acres for pocket ponds.
Underlying Soils	Low permeability soils are best (NRCS Hydrologic Soil Group A and B soils require modifications to maintain a permanent pool unless groundwater is intercepted).
Capacity	The minimum ratio of pool volume to runoff volume must be greater than 2:1 and preferably 4:1. A 4:1 ratio provides 85-90% sediment removal based on a residence time of two weeks.
Depth	❍ An average pool depth of 3 to 6 feet is recommended and varying depths in the pond are preferred. ❍ The aquatic bench should be 12-18 inches deep. ❍ Ponds should not be greater than 8 feet deep.

1 Minimum requirements. State and local requirements supercede.

Design Criteria

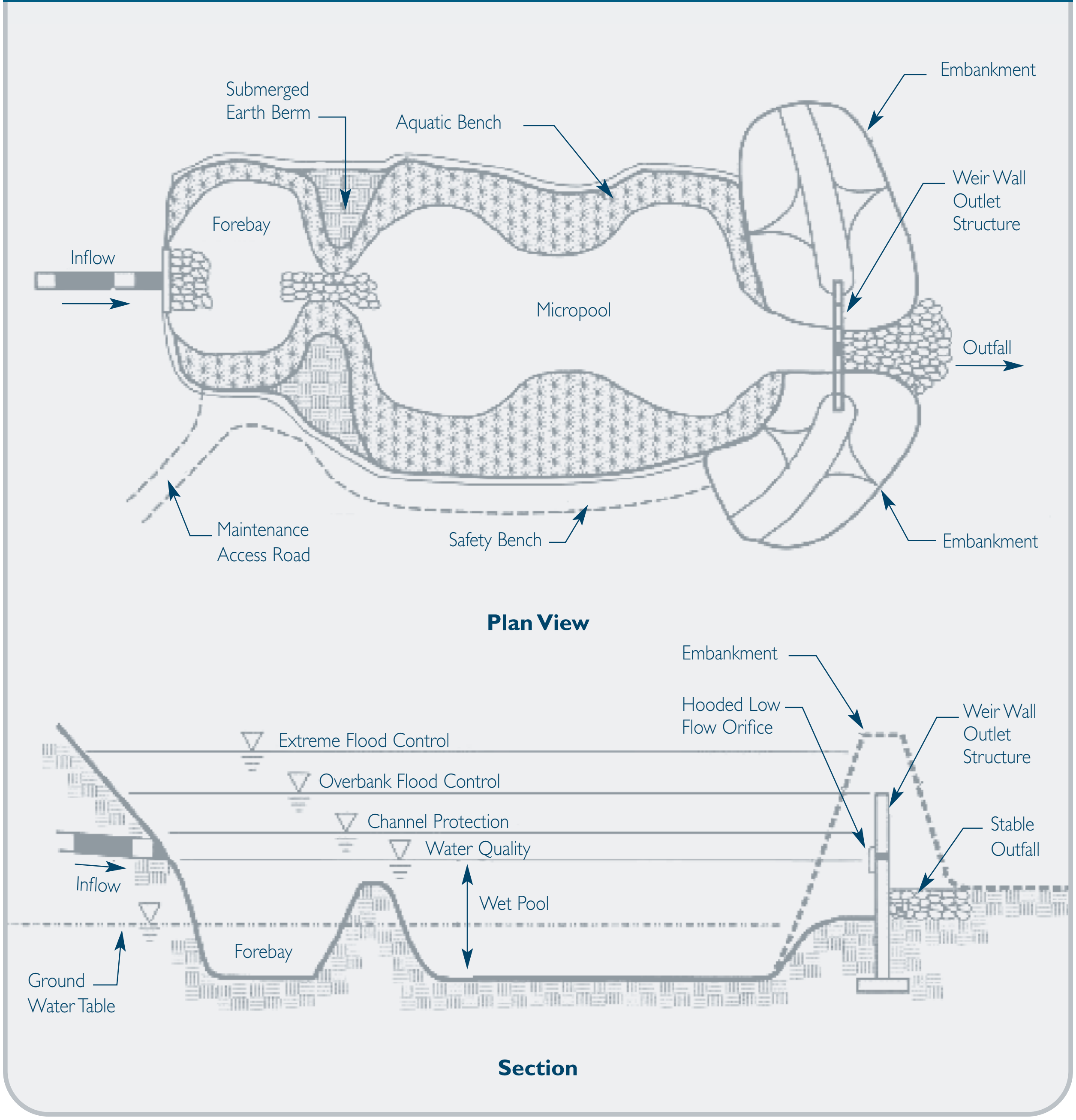
Pond designs may vary considerably due to site constraints, local requirements, or the designer's preferences. Design considerations for stormwater ponds are presented below and summarized in **Table 11-P1-1.**

Forebay

A sediment forebay is recommended for all wet pond systems. The purpose of the forebay is to provide pretreatment by settling out coarse sediment particles, which will enhance treatment performance, reduce maintenance, and increase the longevity of a stormwater pond. A forebay is a separate cell within the pond formed by a barrier such as an earthen berm, concrete weir, or gabion baskets.

- *The forebay should be sized to contain at least 10 percent of the WQV and be of an adequate depth to prevent resuspension of collected sediments during the design storm, often being four to six feet deep. The goal of the forebay is to at least remove particles consistent with the size of medium sand. The forebay storage volume may be used to fulfill the total WQV requirement of this system. The forebay must also include additional sediment storage volume that may not be used for WQV calculations.*
- *The outlet from the forebay should be designed in a manner that prevents erosion of the embankment and primary pool. This outlet can be configured in a number of ways including a culvert, weir, or spillway channel. The outlet should be designed to convey the same design flow proposed to enter the basin. The outlet invert must be elevated in a manner such that 10 percent of the WQV can be stored below it in addition to the required sediment volume.*
- *The forebay should have a minimum length to width ratio of 2:1 and a preferred length to width ratio of 3:1.*

Figure 11-P1-2 Pocket Pond



Source: Adapted from NYDEC, 2001.

Table 11-P1-2 Water Quality Volume Distribution in Pond Designs

Design Variation	Percent of Water Quality Volume (WQV)	
	Permanent Pool	Extended Detention
Wet Pond	100%	0%
Micropool Extended Detention Pond	20% min.	80% max.
Wet Extended Detention Pond	50% min.	50% max.
Multiple Pond System	50% min.	50% max.
Pocket Pond	50% min.	50% max.

Source: NYDEC, 2001.

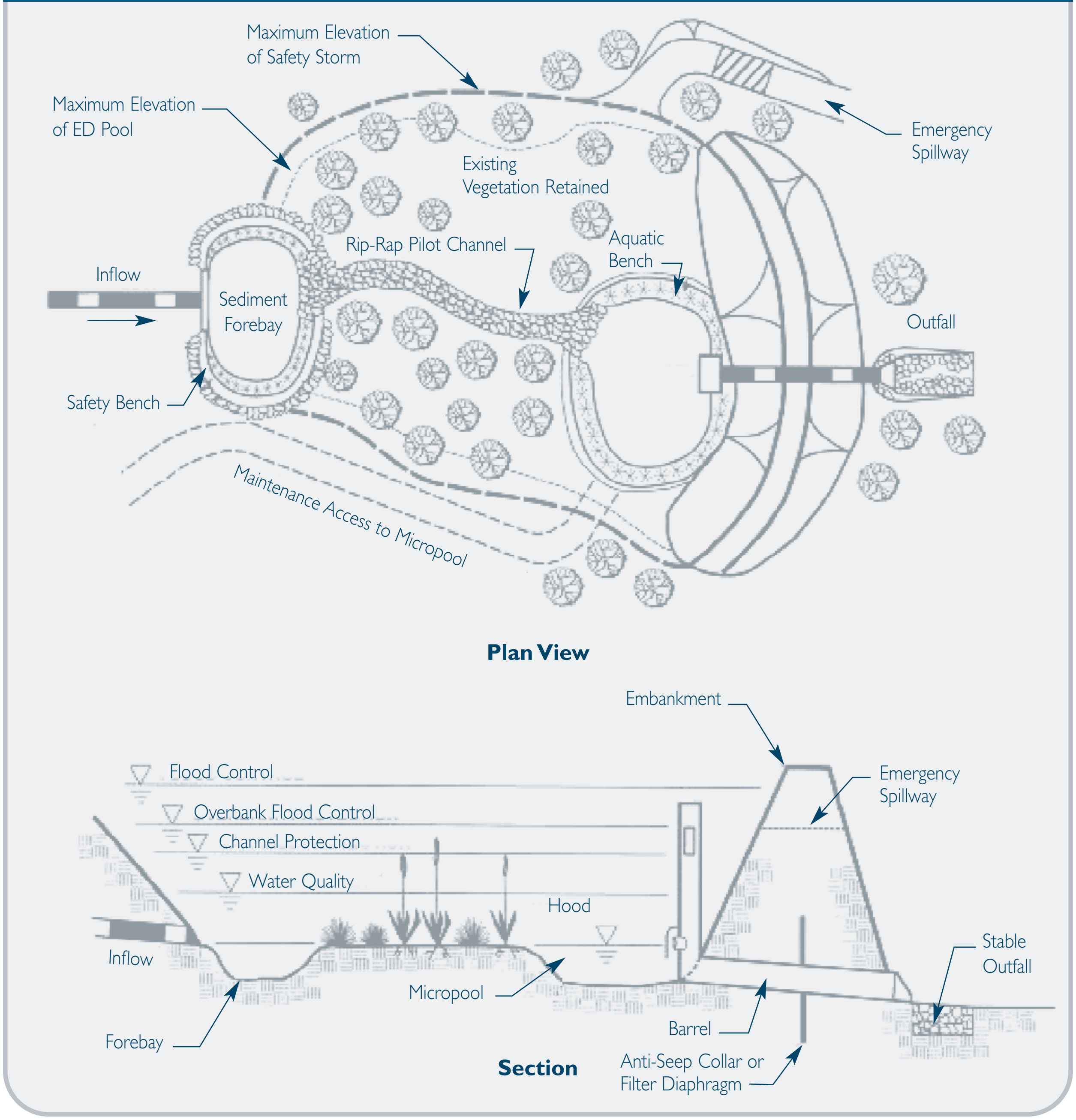
- *Direct access for appropriate maintenance equipment should be provided to the forebay and may include a ramp to the bottom if equipment cannot reach all points within the forebay from the top. The forebay can be lined with a concrete pad to allow easy removal of sediment and to minimize the possibility of excavating subsurface soils or undercutting embankments during routine maintenance.*
- *A fixed vertical sediment depth marker should be installed in the forebay to measure sediment deposition.*
- *A barrier, such as an earthen berm, gabions, or a concrete weir may be used to separate the forebay from the permanent pool. This barrier should be armored as necessary to prevent erosion of the embankment if it overtops. This armoring could consist of materials such as riprap, pavers, or geosynthetics designed to resist slope erosion. If a channel is used to convey flows from the forebay to the pond, the side slopes of the channel must be armored as well.*
- *Additional pretreatment can be provided in the forebay by raising the embankment to provide some detention of incoming flows.*

Wet Pool

Stormwater pond design features primarily enhance the removal of pollutants by increasing the residence time of stormwater in the pond and providing habitat for aquatic plants.

- *Provide water quality treatment storage to capture the computed WQV from the contributing drainage area in the proposed forebay, permanent pool, extended detention area, and marsh. The division of storage between the permanent pool and extended detention is outlined in* ***Table 11-P1-2.***
- *Water quality storage can be provided in multiple cells. Performance is enhanced when multiple treatment pathways are provided by using multiple cells, longer flow paths, high surface area to volume ratios, complex microtopography, and/or redundant treatment methods (combinations of pool, extended detention, and marsh).*
- *The minimum pool size should be equal to the WQV. A larger volume should be used to achieve greater pollutant removal when it is necessary to meet specific water quality standards.*
- *Underwater or marsh berms may be incorporated in the design to lengthen the flow path through the pond.*
- *Shade should be provided, at a minimum, at least at the pond outlet in an effort to mitigate warming of discharge water.*
- *The minimum length:width ratio for the pond is 3:1.*
- *Upper stages of the pond should provide temporary storage of large storms (10, 25, or 100-year events) to control peak discharge rates.*
- *Provide variable pond depths of 4 to 6 feet but not exceeding depths of 8 feet. Maintaining pond water depths in excess of 4 feet precludes invasive emergent vegetation such as cattails. Emergent vegetation provides mosquito larvae with refuge from predators and increases nutrient availability.*
- *Chemicals (e.g., aluminum sulfate or alum) can be injected into pond stormwater discharges or added directly to the permanent pool or*

Figure 11-P1-3 Micropool Extended Dentention Pond



Source: Adapted from NYDEC, 2001.

sediment forebay to enhance removal of fine particulates and dissolved pollutants within the pond.

- *Maintain pond water quality sufficient to support mosquito-feeding fish. Stormwater ponds often develop mini-ecosystems where birds, frogs, and other insects feed, many of which are natural predators of mosquitoes and nuisance insects. Ponds can also be stocked with predatory fish native to Connecticut that feed on mosquito larvae such as banded sunfish, flathead minnows, Eastern mud minnows, and several species of killfish. The DEP Fisheries Division should be consulted regarding species selection. Other natural predators of mosquitoes such as dragonfly nymphs can also be used.*

Conveyance

Stormwater should be conveyed to and from all stormwater management practices safely and to minimize erosion potential.

Inlet Protection

- *The number of inlets should be minimized and one inlet is preferable. The inlet should be located at the most hydraulically remote point from the outlet to minimize the potential for short-circuiting, and should be located in a manner that meets or exceeds desired length to width ratios.*
- *Inlet areas should be stabilized to ensure that non-erosive conditions exist for the design storm event.*
- *The ideal inlet configuration is above the permanent pool to prevent potential hydraulic constrictions due to freezing.*

Outlet Protection

- *The channel immediately below a pond outfall should be modified to prevent erosion and conform to natural topography by use of a plunge pool or a riprap pad and sized for peak discharge velocities.*
- *Outlet protection should be used to reduce flow to non-erosive velocities from the principal spillway based on actual cover and soil conditions.*
- *If a pond outlet discharges to a perennial stream or channel with dry weather base flow, tree clearing should be minimized and a forested riparian zone re-established.*
- *To convey potential flood flows from the basin, an armored emergency spillway should be provided.*

Pond Liners

- *When a pond is located such that the permanent pool does not intercept groundwater, a liner may be needed to maintain minimum water levels. Pond liners are also necessary for ponds that may present a risk to groundwater quality.* ***Table 11-P1-3*** *lists recommended specifications for clay and geomembrane liners.*

Pond Benches

- *For pond side slopes steeper than 4:1, provide a flat safety bench that extends 10 feet outward from the normal water edge to the toe of the pond side slope.*
- *Incorporate a flat aquatic bench that extends 10 feet inward from the normal shoreline at a depth of 12-18 inches below the normal pool water surface elevation.*

Table 11-P1-3 Linear Specifications

Linear Material	Property	Recommended Specifications
Clay	Minimum Thickness	6 to 12 inches
	Permeability	1×10^{-5} cm/sec[1]
	Particle Size	Minimum 15% passing #200 sieve[1]
Geomembrane	Minimum Thickness	30 mils (0.03 inches)
	Material	Ultraviolet resistant, impermeable poly-liner

Source: [1]NYDEC, 2001; all other listed specifications from City of Austin in Washington, 2000 (in Metropolitan Council, 2001).

Maintenance Reduction Features

In addition to regular maintenance activities needed to maintain the function of stormwater practices, some design features can be incorporated to ease the maintenance burden of each practice. In wet ponds, maintenance reduction features include techniques to reduce the amount of maintenance needed, as well as techniques to make regular maintenance activities easier.

- *Ponds should be designed with non-clogging outlets, such as a weir, or by incorporating trash racks for culverts and orifice openings.*
- *To prevent clogging from ice or floatables, a reverse slope outlet pipe can be used to draw water from below the permanent pool up to the outlet structure. The invert of the pipe drawing from the pool should be at least 18 inches from the bottom to prevent sediment discharge.*
- *No orifice should be less than 6 inches in diameter with a trash rack to prevent clogging.*
- *Ponds should have a manually operated drain to draw down the pond for infrequent maintenance or dredging of the main cell of the pond.*
- *Metal components of outlet structures should be corrosion resistant, but not galvanized due to the contribution of zinc to water.*
- *Outlet structures should be resistant to frost heave and ice action in the pond.*

Landscaping

Constructing landscaped wet ponds can enhance their aesthetic value. Aquatic plantings around the edge of the pond can provide pollutant uptake, stabilize the soil at the edge of the pond, and improve habitat. Maintaining high vegetation along the edge of the pond (not mowing to the edge) can also deter waterfowl access and filter pollutants.

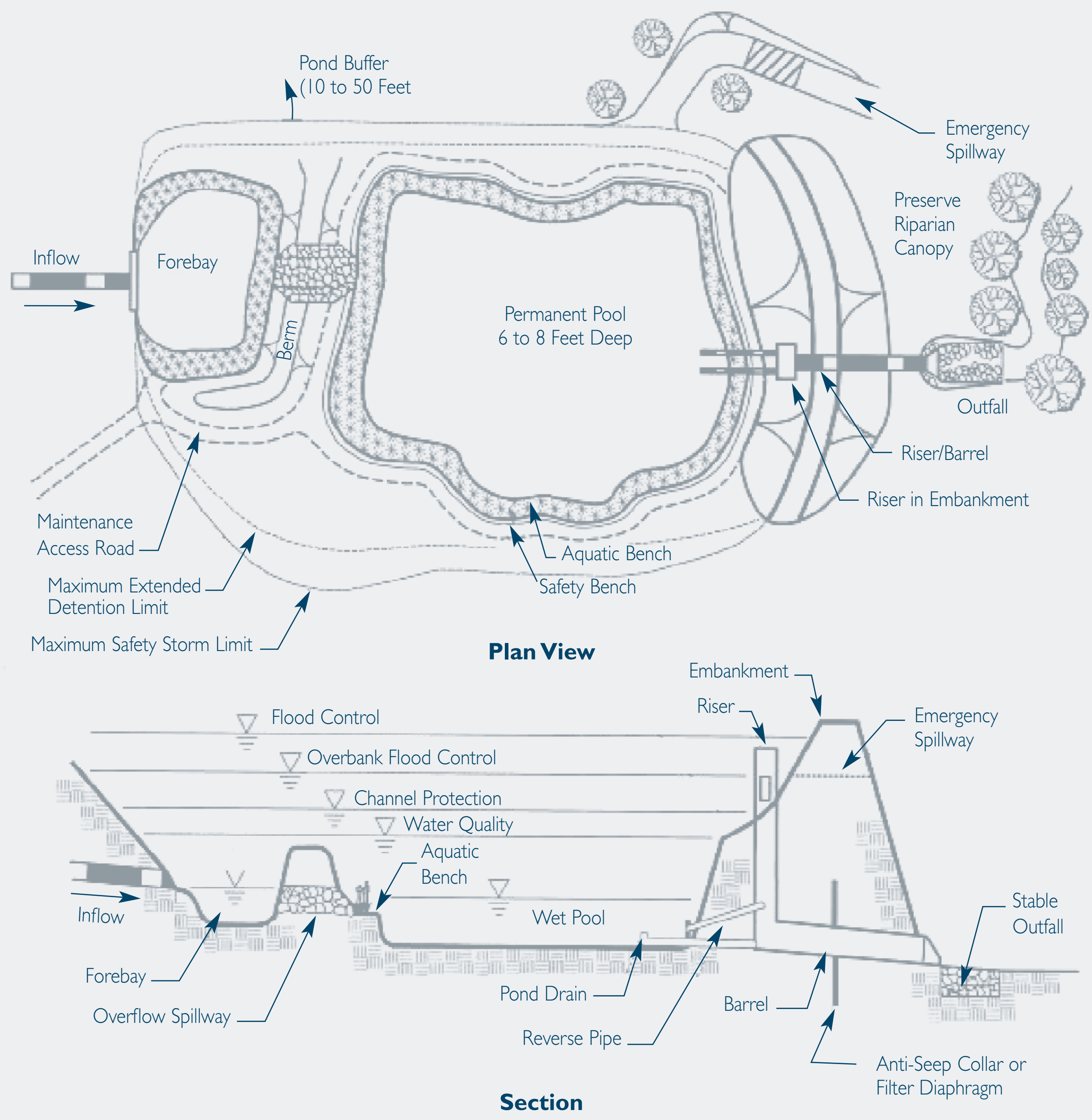
- *Wetland plantings should be encouraged in a pond design, either along the aquatic bench (fringe wetlands), the safety bench and side slopes, or within shallow areas of the pool.*
- *The best depth for establishing wetland plants, either through transplantation or volunteer colonization, is within approximately six inches of the normal pool elevation.*
- *Soils should be modified (e.g., scarified or tilled) to mitigate compaction that occurs during construction around the proposed planting sites.*
- *Avoid species that require full shade, are susceptible to winterkill, or are prone to wind damage.*
- *Woody vegetation may not be planted or allowed to grow within 25 feet of the toe of the embankment and 25 feet from the principal spillway structure.*
- *Existing trees should be preserved in the buffer area during construction. It is desirable to locate forest conservation areas adjacent to ponds. To help discourage resident geese populations, the buffer can be planted with trees, shrubs, and native ground covers.*
- *Annual mowing of the pond buffer is only required along maintenance rights-of-way and the embankment. The remaining buffer can be managed as a meadow (mowing every other year) or forest.*
- *Plant the pond with salt-tolerant vegetation if the stormwater pond receives road runoff.*

Cold Climate Pond Design Considerations

The following design elements should be considered to minimize potential performance impacts caused by cold weather:

- *Inlet pipes should not be submerged, since this can result in freezing and upstream damage or flooding.*
- *Bury all pipes below the frost line to prevent frost heave and pipe freezing. Bury pipes at the point furthest from the pond deeper than the frost line to minimize the length of pipe exposed.*
- *Increase the slope of inlet pipes to a minimum of 1 percent, if site conditions allow, to prevent standing water in the pipe and reduce the potential for ice formation.*
- *If perforated riser pipes are used, the minimum orifice diameter should be 0.5 inches. In addition, the pipe should have a diameter of at least 6 inches.*
- *When a standard weir is used, the minimum slot width should be 3 inches, especially when the slot is tall.*
- *Baffle weirs can prevent ice formation near the outlet by preventing surface ice from blocking the inlet, encouraging the movement of base flow through the system.*
- *In cold climates, riser hoods and reverse slope pipes should draw from at least 6 inches below the typical ice layer. This design encourages circulation in the pond, preventing stratification and formation of ice at the outlet. Reverse slope pipes should not be used for off-line ponds.*

Figure 11-P1-4 Wet Extended Detention Pond



Source: Adapted from NYDEC, 2001.

Table 11-P1-4 Typical Maintenance Activities for Stormwater Ponds

Activity	Schedule
❍ If wetland components are included, inspect for invasive vegetation.	Semi-annual inspection
❍ Inspect for damage. ❍ Note signs of hydrocarbon build-up, and remove if detected. ❍ Monitor for sediment accumulation in the facility and forebay. ❍ Examine to ensure that inlet and outlet devices are free of debris and operational.	Annual inspection
❍ Repair undercut or eroded areas.	As needed maintenance
❍ Clean and remove debris from inlet and outlet structures. ❍ Mow side slopes. High grass along pond edge will discourage waterfowl from taking up residence and serve to filter pollutants.	Monthly maintenance
❍ Wetland plant management and harvesting. ❍ Drain pond in fall and let frost kill plants, then dredge in spring.	Annual maintenance (if needed)
❍ Removal of sediment from the forebay.	5 year maintenance
❍ Remove sediment when the pool volume has become reduced significantly, or when significant algal growth is observed.	10 year maintenance; more frequent dredging in developing watersheds with significant sediment loads

Source: Adapted from WMI, 1997.

- *Trash racks should be installed at a shallow angle to prevent ice formation.*
- *Additional storage should be provided to account for storage lost to ice buildup. Ice thickness may be estimated by consulting with local authorities (e.g. the fire department) with knowledge of the typical ice thickness in the area.*

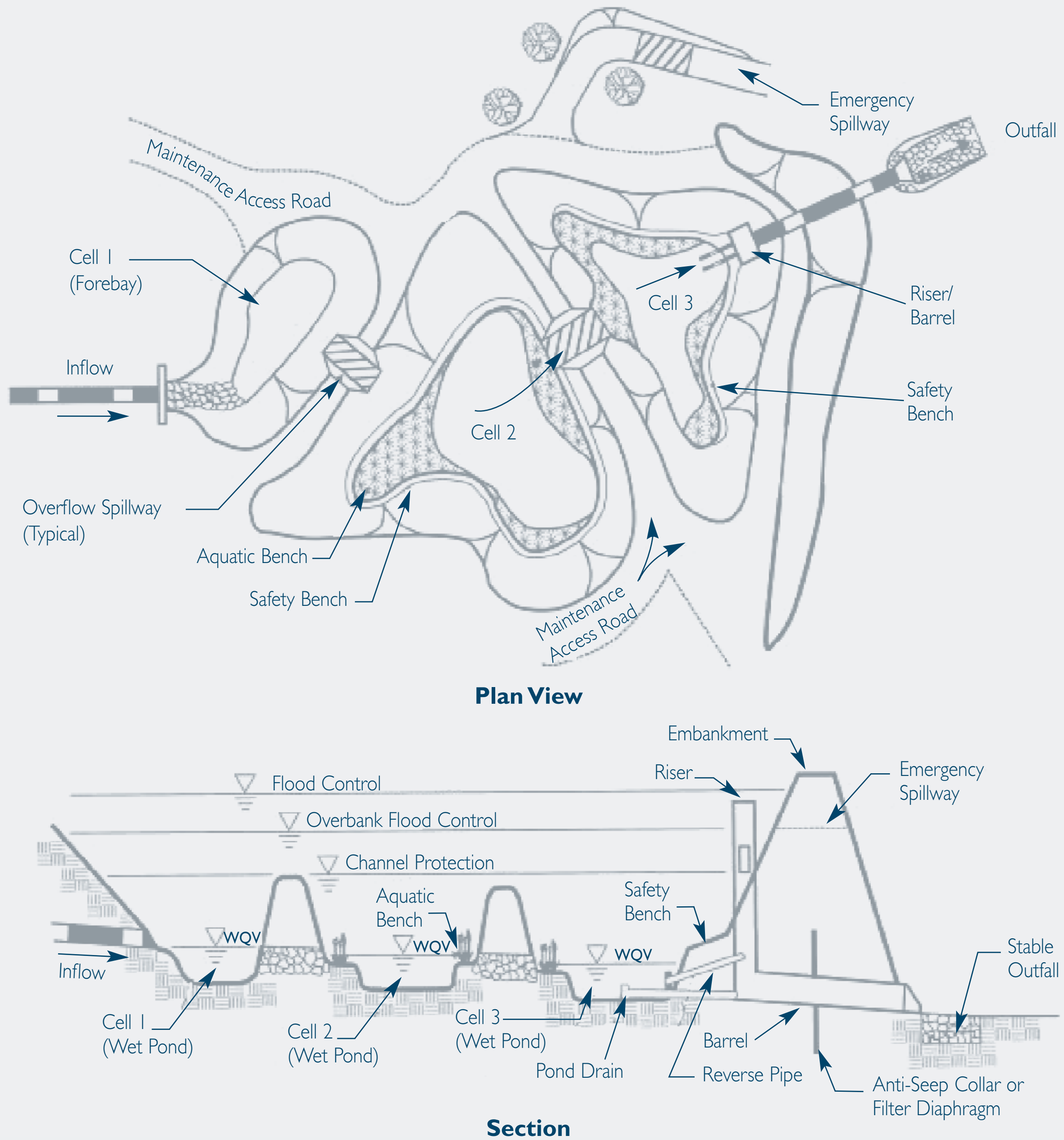
Construction

- *Any stormwater treatment practices that create an embankment, including stormwater ponds, are under the jurisdiction of the Dam Safety Section of the Connecticut DEP Inland Water Resources Division (IWRD) and should be constructed, inspected, and maintained in accordance with Connecticut General Statutes §§22a-401 through 22a-411, inclusive, and applicable DEP guidance.*
- *Avoid soil compaction to promote growth of vegetation.*
- *Temporary erosion and sediment controls should be used during construction and sediment deposited in the stormwater pond should be removed after construction.*
- *Appropriate soil stabilization methods should be used before permanent vegetation is established. Seeding, sodding, and other temporary soil stabilization controls should be implemented in accordance with the* Connecticut Guidelines for Soil Erosion and Sediment Control*.*
- *Temporary dewatering may be required if excavation extends below the water table. Appropriate sedimentation controls will be required for any dewatering discharges.*

Inspection and Maintenance

- *Plans for stormwater ponds should identify detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance.*
- *The principal spillway should be equipped with a removable trash rack, and generally accessible from dry land.*
- *Sediment removal in the forebay should occur at a minimum of every five years or after the sediment storage capacity in the forebay capacity has been filled.*

Figure 11-P1-5 Multiple Pond System



Source: Adapted from NYDEC, 2001.

- *Sediment removed from stormwater ponds should be disposed of according to an approved comprehensive operation and maintenance plan.*
- *Recommended maintenance activities for stormwater ponds are summarized in* ***Table 11-P1-4.***

Maintenance Access

- *A maintenance right-of-way or easement should extend to the pond from a public road.*
- *Maintenance access should be at least 12 feet wide, have a maximum slope of no more than 15 percent, and be appropriately stabilized to withstand maintenance equipment and vehicles.*
- *The maintenance access should extend to the forebay, safety bench, riser, and outlet and be designed to allow vehicles to turn around.*

Non-clogging Low Flow Orifice

- *A low flow orifice shall be provided, with the size of the orifice sufficient to ensure that no clogging will occur.*
- *The low flow orifice should be adequately protected from clogging by either an acceptable external trash rack (recommended minimum orifice of 6 inches) or by internal orifice protection that may allow for smaller diameters (minimum of 1 inch).*
- *The preferred method is a submerged reverse-slope pipe that extends downward from the riser to an inflow point one foot below the normal pool elevation.*
- *Alternative methods are to employ a broad crested rectangular, V-notch, or proportional weir, protected by a half-round pipe that extends at least 12 inches below the normal pool level.*
- *The use of horizontally extended perforated pipe protected by geotextile fabric and gravel is not recommended. Vertical pipes may be used as an alternative if a permanent pool is present.*

Riser in Embankment

- *The riser must be located within the embankment for maintenance access, safety and aesthetics.*
- *Lockable manhole covers and manhole steps within easy reach of valves and other controls should provide access to the riser. The principal spillway opening should be "fenced" with pipe at 8-inch intervals for safety purposes.*

Pond Drain

- *Except where local slopes prohibit this design, each pond should have a drain pipe that can completely or partially drain the pond. The drain pipe shall have an elbow or protected intake within the pond to prevent sediment deposition in the pipe, and a diameter capable of draining the pond within 24 hours.*
- *Pond retention times can be increased to enhance water quality control during storm events by maintaining ponds at low levels before storms and increasing the available pond volume during storms.*
- *Care should be exercised during pond draining to prevent rapid drawdown and minimize downstream discharge of sediments or anoxic water. The approving jurisdiction should be notified before draining a pond.*

Adjustable Gate Valve

- *Both the WQV extended detention pipe and the pond drain may be equipped with an adjustable gate valve, typically a handwheel activated knife gate valve.*
- *Valves should be located inside of the riser at a point where they will not normally be inundated and can be operated in a safe manner.*
- *Both the WQV extended detention pipe and the pond drain should be sized one pipe size greater than the calculated design diameter.*
- *To prevent vandalism, the handwheel should be chained to a ringbolt, manhole step, or other fixed object.*

Safety Features

- *Side slopes to the pond should not exceed 3:1 and should terminate at a safety bench.*
- *The principal spillway opening must not permit access by small children, and endwalls above pipe outfalls greater than 48 inches in diameter must be fenced to prevent a hazard.*
- *Both the safety bench and the aquatic bench may be landscaped to prevent access to the pool.*
- *Warning signs prohibiting swimming and skating should be posted.*
- *Pond fencing is generally not encouraged, but may be required by some municipalities. The preferred method is to grade the pond to eliminate dropoffs or other safety hazards.*

Cost Considerations

Wet ponds are relatively inexpensive stormwater practices, but costs vary widely depending on the complexity of the design or difficulty of site constraints. The costs of stormwater ponds may be estimated using the following equation (Brown and Schueler, 1997):

$$C = 24.5V^{0.705}$$

where: C = Construction, design, and permitting cost.
V = Volume in the pond to include the 10-year storm (ft^3).

Costs should be adjusted for inflation to reflect current costs. The annual cost of routine maintenance is typically estimated at about 3 to 5 percent of the construction cost (EPA Wet Pond Fact Sheet, http://www.epa.gov/npdes/menuofbmps/menu.htm). Ponds typically have a design life longer than twenty years.

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Stormwater Wetlands

Source: Nonpoint Education for Municipal Officials (NEMO).

Treatment Practice Type

Primary Treatment Practice	●
Secondary Treatment Practice	

Stormwater Management Benefits

Pollutant Reduction	
Sediment	■
Phosphorus	■
Nitrogen	■
Metals	■
Pathogens	▣
Floatables*	■
Oil and Grease*	■
Dissolved Pollutants	▣
Runoff Volume Reduction	
Runoff Capture	■
Groundwater Recharge	□
Stream Channel Protection	■
Peak Flow Control	■

Key: ■ Significant Benefit
▣ Partial Benefit
□ Low or Unknown Benefit

*Only if a skimmer is incorporated

Implementation Requirements

Cost ....Moderate
Maintenance........................Moderate

Description

Stormwater wetlands are constructed wetlands that incorporate marsh areas and permanent pools to provide enhanced treatment and attenuation of stormwater flows. Stormwater wetlands differ from stormwater ponds in that wetland vegetation is a major element of the overall treatment mechanism as opposed to a supplementary component. This section includes three types of stormwater wetlands:

- *Shallow Wetland*
- *Extended Detention Shallow Wetland*
- *Pond/Wetland System*

While stormwater wetlands can provide some of the ecological benefits associated with natural wetlands, these benefits are secondary to the function of the system to treat stormwater. Stormwater wetlands can be very effective at removing pollutants and reducing peak flows of runoff from developed areas. Removal of particulate pollutants in stormwater wetlands can occur through a number of mechanisms similar to stormwater ponds including sedimentation and filtration by wetland vegetation. Soluble pollutants can also be removed by adsorption to sediments and vegetation, absorption, precipitation, microbial decomposition, and biological processes of aquatic and fringe wetland vegetation. Stormwater wetlands are particularly advantageous when nitrogen and/or dissolved pollutants are a concern.

The key to maximizing pollutant removal effectiveness in stormwater wetlands is maintaining wet conditions adequate to support wetland vegetation. To achieve this, the constructed wetlands must either intercept the groundwater table or must be lined with an impermeable liner and have a watershed large enough to supply storm flows that will maintain wetness even during dry periods.

Stormwater wetland systems should be designed to operate on the plug flow principle where incoming water displaces the water retained in the system from the previous storm event. This is accomplished by maximizing length versus width ratios and/or by creating distinct cells along the treatment path. Ideally, the wetland system would be designed to retain the water quality volume (WQV) between storm events. As a result, storms that generate runoff less than the WQV would be entirely retained while only a percentage of the runoff from storms that generate more than the WQV would be retained. The value provided by this process is that a portion of the "new" polluted runoff is retained, and the "old" treated water is discharged from the wetland, thereby allowing extended treatment of the WQV.

Stormwater wetlands should be equipped with a sediment forebay or similar form of pretreatment to minimize the discharge of sediment to the primary treatment wetland. High solids loadings to the system will degrade system performance and result in more frequent cleaning, which could result in additional disturbance to the wetland vegetation. A micropool or permanent pool is often included just prior to the discharge for additional solids removal.

Design Variations

There are several common stormwater wetland design variations. The various designs are characterized by the volume of the wetland in the deep pool, high marsh, and low marsh zones, and whether the design allows for detention of small storms above the permanent pool.

Shallow Wetland: Most shallow wetland systems, also referred to as shallow marsh wetlands, consist of aquatic vegetation with a permanent pool ranging from 6 to 18 inches during normal conditions. Shallow wetlands are designed such that flow through the wetlands is conveyed uniformly across the treatment area. While pathways, streams or other varied water depths could enhance the aesthetic or ecosystem value of the wetland, they could also cause short-circuiting through the wetland thereby reducing the overall treatment effectiveness. As a result, to maximize treatment performance, providing a uniformly sloped system is recommended. In order to enhance plug flow conditions across the wetland, individual wetland cells can be constructed and separated by weirs. **Figure 11-P2-1** depicts a typical schematic design of a shallow wetland.

Extended Detention Shallow Wetland: Extended detention shallow wetlands provide a greater degree of downstream channel protection as they are designed with more vertical storage capacity. The additional vertical storage volume also provides extra runoff detention above the normal pool elevations. Water levels in the extended detention shallow wetland may increase by as much as three feet after a storm event and return gradually to pre-storm elevations within 24 hours of the storm event. The growing area in extended detention shallow wetlands extends from the normal pool elevation to the maximum water surface elevation. Wetland plants that tolerate intermittent flooding and dry periods should be selected for the extended detention area above the shallow marsh elevations. **Figure 11-P2-2** depicts a typical schematic design of an extended detention shallow wetland.

Pond/Wetland Systems: Multiple cell systems, such as pond/wetland systems, utilize at least one pond component in conjunction with a shallow marsh component. The first cell is typically a wet pond, which provides pretreatment of the runoff by removing particulate pollutants. The wet pond is also used to reduce the velocity of the runoff entering the system. The shallow marsh then polishes the runoff, particularly for soluble pollutants, prior to discharge. These systems require less space than the shallow marsh systems since more of the water volume is stored in the deep pool which can be designed to reduce peak flows. Because of this system's ability to significantly reduce the velocity and volume of incoming peak flows (i.e., flow equalization or dampening), it can often achieve higher pollutant removal rates than other similarly sized stormwater wetland systems. **Figure 11-P2-3** depicts a typical schematic design of a pond/wetland system.

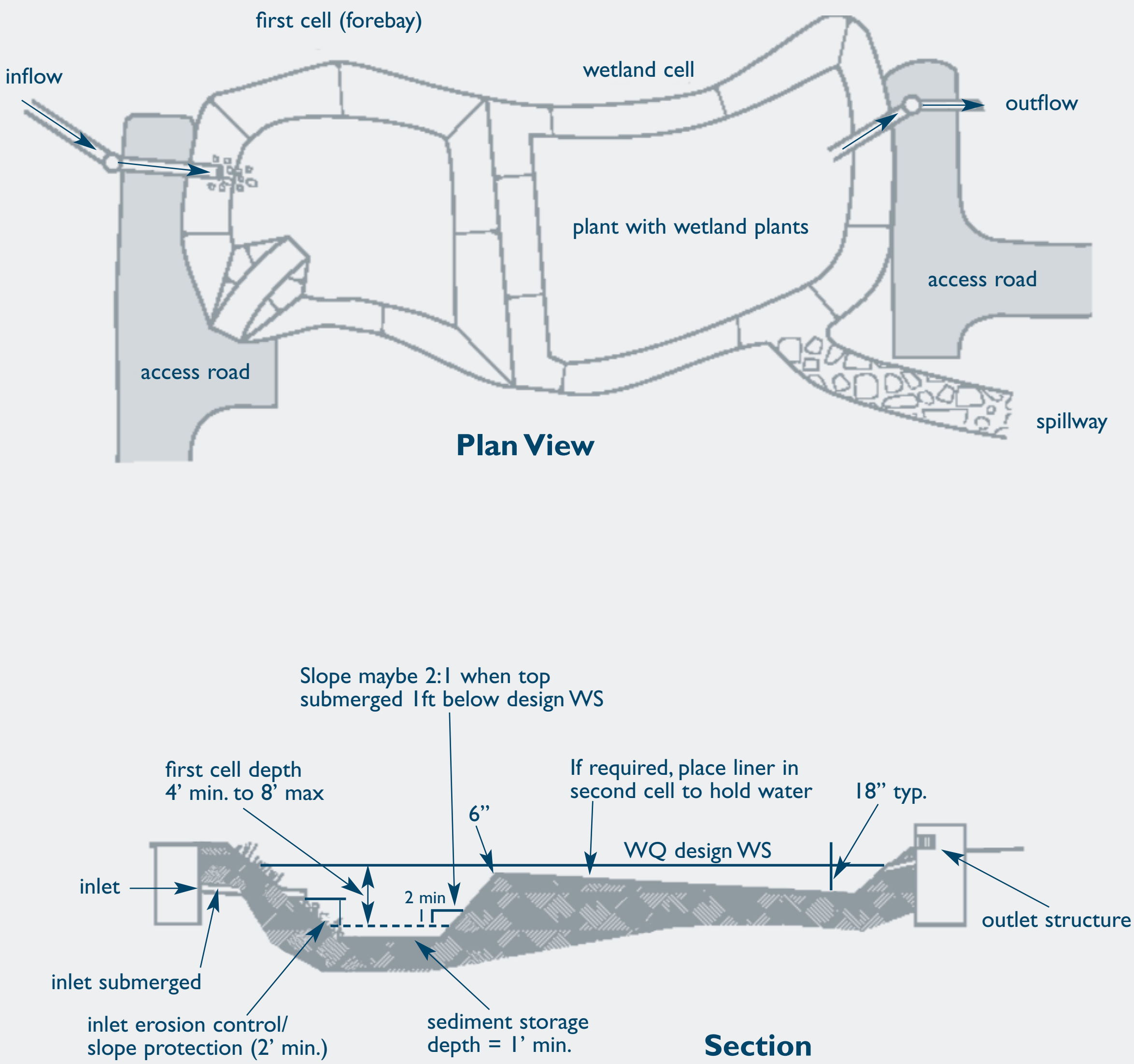
Advantages

- *Efficient at removing both particulate and soluble pollutants.*
- *Capable of providing aesthetic benefits.*
- *Capable of providing wildlife habitat with appropriate design elements.*
- *Provide ability to attenuate peak runoff flows.*

Limitations

- *More costly than extended detention basins.*
- *Require a relatively large land area that is directly proportional to the size of the contributing drainage area.*
- *Very sensitive to the ability to maintain wet conditions especially during extended dry weather when there may be significant evaporative losses.*

Figure 11-P2-1 Shallow Wetland



Source: Adapted from King County Department of Natural Resources, 1998.

- *May cause thermal impacts to receiving waters and thereby should not discharge directly to cold water fish habitats.*
- *Potential breeding habitat for mosquitoes, particularly for systems with isolated pockets of standing water (standing longer than 5 days). Circulating water in the permanent pool may minimize this problem. This may be a more significant problem for lined systems.*
- *Wetland systems with steep side slopes and/or deep wet pools may present a safety issue to nearby pedestrians.*
- *Stormwater wetlands can serve as decoy wetlands, intercepting breeding amphibians moving toward vernal pools. If amphibians deposit their eggs in these artificial wetlands, they rarely survive due to the sediment and pollutant loads, as well as fluctuations in water quality, quantity, and temperature.*

Siting Considerations

Drainage Area: Stormwater wetlands that utilize a liner system to maintain the desired permanent pool should have a contributing drainage area that is adequate to maintain minimum water levels. Typically, minimum contributing drainage areas are twenty-five acres, especially for shallow systems. A water budget for the wetlands should be calculated to ensure that evaporation losses do not exceed inflows during warm weather months.

Groundwater: Unlined basins must intersect the groundwater table in order to maintain the desired permanent pool. In this case, the elevations of the basin should be established such that the groundwater elevation is equal to the desired permanent pool elevation. Seasonal variations of groundwater elevations should be considered, which can be very pronounced in low permeability soils.

Land Uses: Land uses will dictate potential pollutants-of-concern and potential safety risks. For those land uses where there is significant potential for soluble pollutants, especially those that are highly susceptible to groundwater transport, the use of a liner is recommended. An impermeable liner may not be required, depending on the risk of downgradient contamination, but a low permeable liner constructed in till soils may be acceptable. Adjacent residential land uses pose the greatest public safety risks where mosquito breeding and water hazards must be considered.

Baseflow: A small amount of baseflow is desirable to maintain circulation and reduce the potential for low dissolved oxygen levels during late summer, and to reduce mosquito breeding. This baseflow can be provided by groundwater infiltrating into either the wetland or the collection system above the pond.

Site Slopes: Steep on-site slopes may result in the need for a large embankment to be constructed to provide the desired storage volume and could require a dam construction permit from the Connecticut DEP. Steep slopes may also present design and construction challenges, and significantly increase the cost of earthwork.

Receiving Waters: The sensitivity of receiving waters should be evaluated to determine whether the effects of the warmer stormwater discharges from the wetland could be detrimental to cold-water fish or other sensitive aquatic species.

Flood Zones: Constructed wetlands should not be located in floodways, floodplains, or tidal lands, especially those that require construction of an embankment. Floodwaters could flush out stored pollutants or damage pond embankments.

Natural Wetlands/Vernal Pools: Natural wetlands and vernal pool depressions should not be used, either temporarily or permanently, as a stormwater pond or wetland. Stormwater wetlands should be located at least 750 feet from a vernal pool. They should not be sited between vernal pools or in areas that are known primary amphibian overland migration routes.

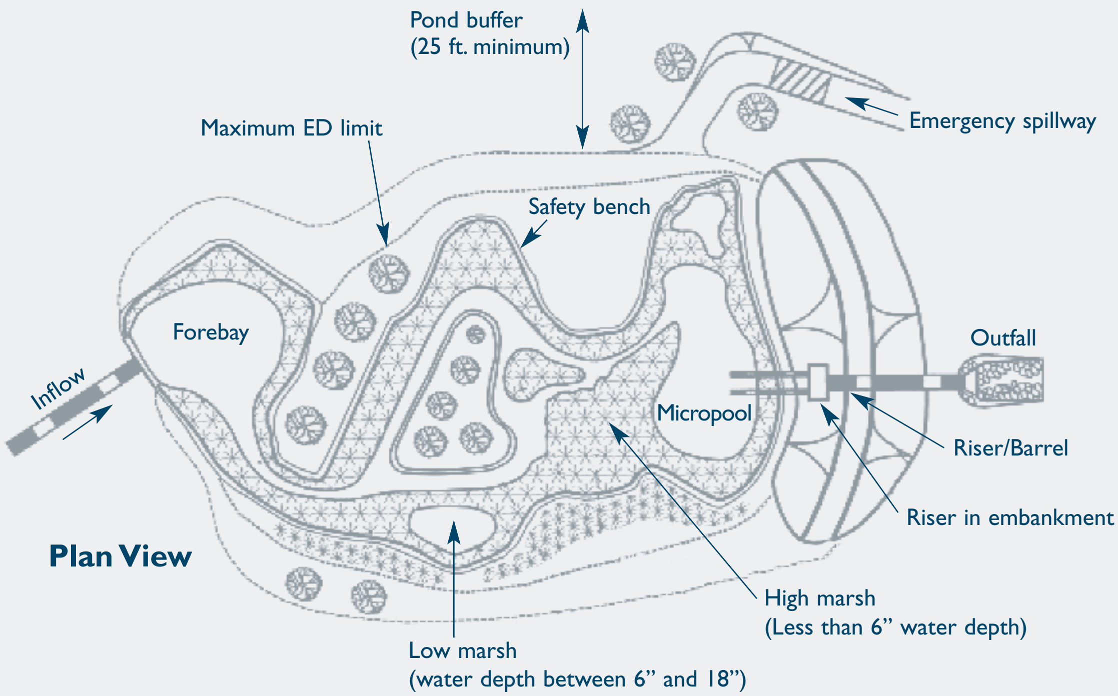
Design Criteria

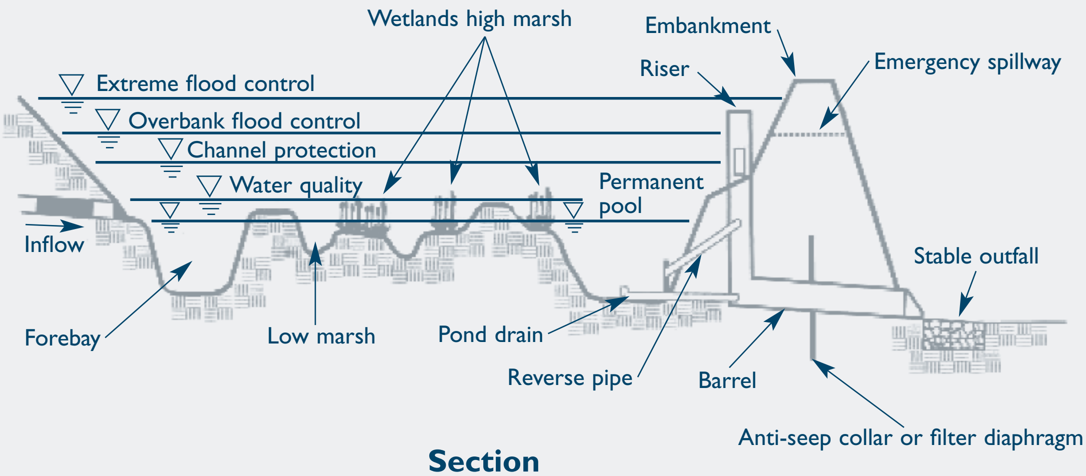
Wetland designs may vary considerably due to site constraints, local requirements, or the designer's preferences. The five common design elements that should be considered for all stormwater wetlands are:

- *Pretreatment*
- *Treatment*
- *Conveyance*
- *Maintenance reduction*
- *Landscaping*

Design considerations for stormwater wetlands are presented below and summarized in **Table 11-P2-1**.

Figure 11-P2-2 Extended Detention Shallow Wetland





Source: Adapted from NYDEC, 2001.

Table 11-P2-1 Design Criteria for Stormwater Wetlands

Parameter	Design Criteria
Setback requirements[1]	❍ 50 feet from on-site sewage disposal system ❍ 50 feet from private well ❍ 10 feet from property line ❍ 20 feet from any structure ❍ 50 feet from any steep slope (greater than 15%) ❍ 750 feet from a vernal pool
Preferred Shape	Curvilinear
Side Slopes	3:1 maximum or flatter preferred
Length to Width Ratio	3:1 minimum along the flow path between the inlet and outlet; flow length is the length at mid-depth. Mid-depth is (avg. top width+avg. bottom width)/2
Pretreatment Volume	Forebays are highly recommended for stormwater wetlands and sized to contain at least 10% of the WQV. Outlet micropools should also be sized to contain 10% of the WQV. For sites with potential for higher pollutant loads, 100% of the WQV must receive pretreatment.
Drainage Area	Minimum contributing drainage area is typically 25 acres. Stormwater wetland should have a surface area at least 1 to 1.5% of the contributing watershed area.
Underlying Soils	Low permeability soils are best (NRCS Hydrologic Soil Group A and B soils require modifications to maintain a permanent pool unless groundwater is intercepted).
Size	The size of the wetland area will be based on desired pollutant removal efficiencies and the depth of water available to store the WQV. Suggested guidelines for the ratio of wetland to watershed areas is 0.2 for shallow marshes and 0.01 for extended detention shallow wetland systems and pond/wetlands.
Depth	Average water levels in the marsh/wetland areas can vary between 0.5 and 1.5 feet. Maximum water depths will depend on the site topography and the design of the system. Forebays and micropools should typically have a permanent pool depth of between 4 and 6 feet.

[1]Minimum requirements. State and local requirements supercede.

Source: Adapted from MADEP, 1997 and Schueler, 1992.

Forebay

A sediment forebay is recommended for all stormwater wetland systems. Sediment forebays provide pretreatment by settling out coarse solids, which enhances treatment performance, reduces maintenance, and increases the longevity of the system. This is especially critical in wetland systems where removal of solids would disturb existing wetland vegetation and temporarily affect treatment performance.

- *The forebay should be sized to contain at least 10 percent of the WQV and have an adequate depth to prevent resuspension of collected sediments during the design storm, often being 4 to 6 feet deep. Maintaining water depths in excess of 4 feet precludes invasive emergent vegetation such as cattails. Emergent vegetation provides mosquito larvae with refuge from predators and increases nutrient availability.*
- *In larger open water areas of the wetland system (forebay and micropool), maintain water quality sufficient to support mosquito-feeding fish. Stormwater ponds and wetlands often develop mini-ecosystems where birds, frogs, and other insects feed, many of which are natural predators of mosquitoes and nuisance insects. Ponds can also be stocked with predatory fish native to Connecticut that feed on mosquito larvae such as banded sunfish, flathead minnows, Eastern mud minnows, and several species of killfish. The DEP Fisheries Division should be consulted regarding species selection. Other natural predators of mosquitoes such as dragonfly nymphs can also be used.*
- *The forebay must also include additional sediment storage volume that may not be used for WQV calculations.*

- *The outlet from the forebay should be designed in a manner to evenly distribute flow across the wetland/marsh area and prevent erosion of the embankment. This outlet can be configured in a number of ways, including a culvert with a distribution header or spillway channel. The outlet should be designed to safely convey the same design flow that is proposed to enter the basin. The outlet invert must be elevated in a manner such that 10 percent of the WQV can be stored below it in addition to the required sediment volume.*
- *The forebay should have a minimum length to width ratio of 2:1 and a preferred length to width ratio of 3:1.*
- *Direct access for appropriate maintenance equipment should be provided to the forebay and may include a ramp to the bottom if equipment cannot reach all points within the forebay from the top. The forebay can be lined with a concrete pad to allow easier removal of sediment and to minimize the possibility of excavating subsurface soils or undercutting embankments during routine maintenance.*
- *A fixed vertical sediment depth marker should be installed in the forebay to measure sediment deposition.*
- *A barrier, such as an earthen berm, gabions, or a concrete weir may be used to separate the forebay from the permanent pool. This barrier should be armored as necessary to prevent erosion of the embankment if it overtops. This armoring could consist of materials such as riprap, pavers, or geosynthetics designed to resist slope erosion.*
- *Additional pretreatment can be provided in the forebay by raising the embankment to provide some detention of incoming flows.*

Wetland/Marsh Area

The size of the wetland/marsh area should be based on pollutant influent concentrations, base flow, peak design flow, and desired effluent concentrations. Kadlec and Knight (1996) have developed area-based, first-order wetland design models to predict treatment area requirements. The use of these models is recommended to size the wetland areas. This model is as follows:

General Model:

$J = k(C - C^*)$; *where* $k = k_{20}\,\theta_k^{(T-20)}$, $C^* = C^*_{20}\,\theta_c^{(T-20)}$

Where:
- J = Removal rate (g/m2/yr)
- k = First-order, area-based rate constant (m/yr)
- k_{20} = Rate constant at 20°C (m/yr)
- C = Pollutant concentration (mg/L)
- C^* = Irreducible background concentration (mg/L)
- C^*_{20} = Irreducible background concentration at 20°C (mg/L)
- T = Temperature, °C
- θc = Temperature coefficient for background concentration
- θk = Temperature coefficient for rate constant

Wetland Area (based on modified plug-flow hydraulics):

$$A = Q / HLR = -\frac{Q}{k} \left\langle \ln \left(\frac{C2 - C^*}{C1 - C^*} \right) \right\rangle$$

Where:
- HLR = Hydraulic loading rate (m/yr)
- A = Wetland area at normal pool elevation (m2), excluding habitat islands
- Q = Design inflow rate (m3/yr)
- $C1$ = Inflow concentration (mg/L)
- $C2$ = Outflow concentration (mg/L)

Model Parameter Values (at 20°C):

	BOD	TSS	NH3-N	NO3+NO2-N	TN	TP
K_{20}, *m/yr*	35	1,000	18	35	22	12
θk	1.00	1.00	1.04	1.09	1.05	1.00
C_{20}, *mg/L*	6	5.1+0.16C1	0.0	0.0	1.5	0.02
θc	–	1.065	–	–	–	1.00

BOD = biochemical oxygen demand
TSS = total suspended solids
NH3-N = ammonia nitrogen
NO_3+NO_2-N = nitrate and nitrite nitrogen
TN = total nitrogen
TP = total phosphorus

In order to better simulate plug flow conditions and minimize short-circuiting, individual wetland cells can be constructed along the flow path. Weirs, berms, or shallow marsh areas can be used to form these cells. However, the cells should be designed such that flow is redistributed along the edge of each cell. To reduce the potential for mosquito breeding, incorporate contiguous marsh areas rather than isolated pockets, and slope the marsh areas to the deepest pool.

Infiltration Design and Water Balance

The rate of infiltration through the bottom of the wetland can be estimated by using Darcy's law. For most wetlands, the rate of infiltration is relatively constant. Wetlands act as storage reservoirs, retaining water during precipitation events and releasing it slowly as outlet flow and infiltration. During summer months when evapotranspiration losses are large, pool levels commonly drop episodically below the design operating level and outflow ceases.

Ideally, wetlands should not completely dewater under conditions of normal precipitation. To identify potential problems, a monthly water balance should be analyzed for the proposed wetland. The pool level at the end of each month can be estimated as follows:

$$PL = PL_0 + [BF + (PR \times AW) + (PR \times AD \times RO) - (ET \times AW) - (I \times A)] / A$$

Where:
- PL = Pool depth at the end of month (feet)
- PL_0 = Pool depth from the previous month (feet)
- BF = Total monthly flow into the wetland (acre-feet)
- PR = Total monthly precipitation (feet)
- AW = Area of wetland (acres)
- AD = Area of tributary drainage (acres)
- RO = Weighted Volumetric Runoff Coefficient
- ET = Monthly potential evapotranspiration (feet)
- A = Area inundated at depth PL0 (acres)
- I = Monthly infiltration (feet)

If the calculated pool depth at the end of the month is greater than the normal pool depth established at the outlet, then outflow will occur during that month. The quantity is not important. In months with a net outflow, the beginning pool depth for the next month will equal the normal pool depth.

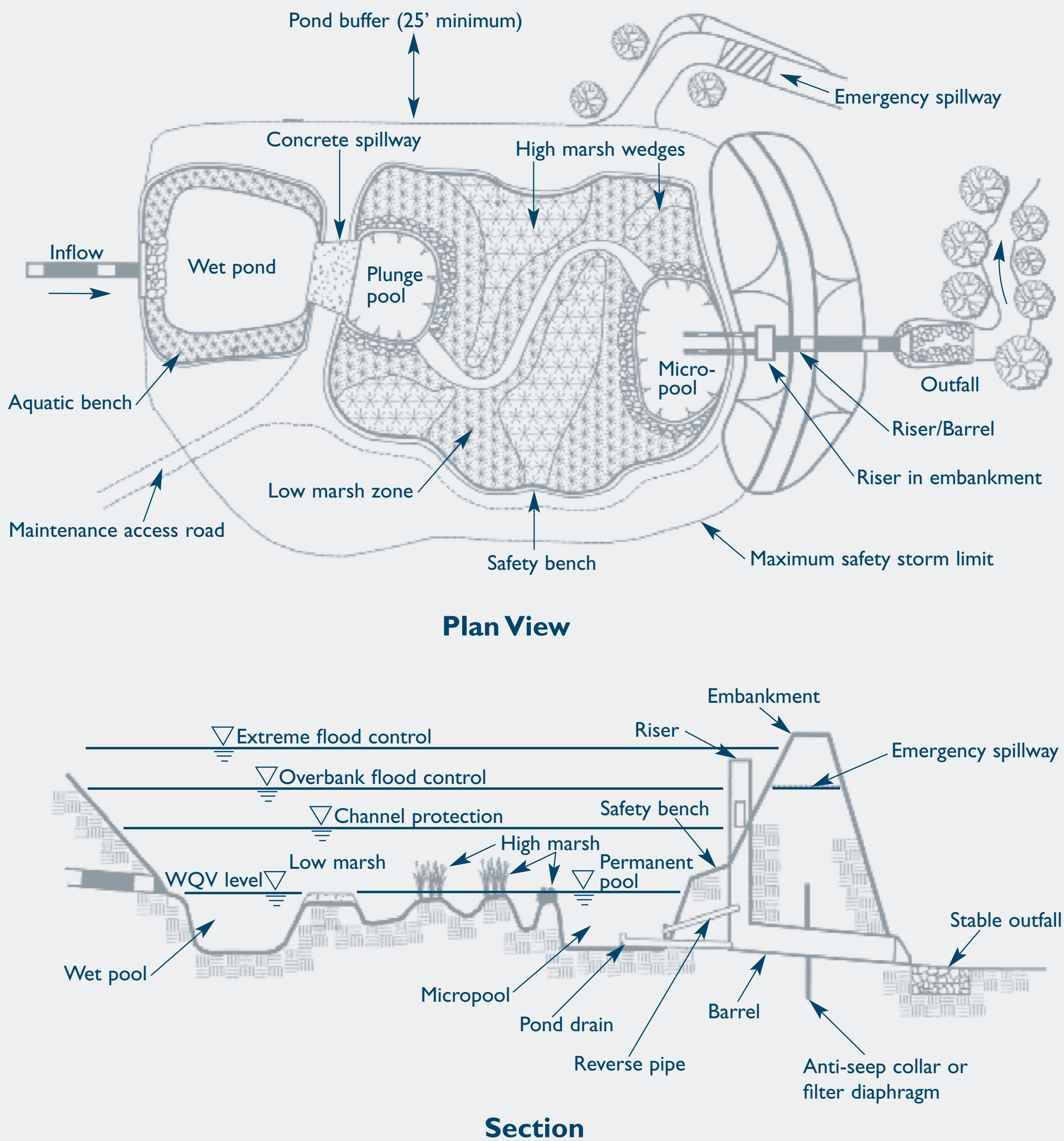
Tables or equations for estimating potential evapotranspiration are available from many sources, including Kadlec and Knight (1996). However, for conceptual design purposes, wetland evapotranspiration can be estimated as 80 percent of the pan evaporation rate.

In most wetlands, the area that is inundated varies with depth. The normal operating pool depth also may be adjusted seasonally to accommodate changes in the water budget. These factors should be accounted for in the calculation. If the water balance predicts that the wetland will dewater, design modifications can be considered, including:

- *Reducing the infiltration rate by adding a clay layer or synthetic liner*
- *Relocating the proposed wetland to increase the contributing drainage area*
- *Increasing the normal operating pool level*

Limitations on increasing the normal pool level will be imposed by the need for shallow water habitat to support emergent plant vegetation. Short periods during which the wetland becomes dry may be tolerated in some instances. However, the selection of plants must be tailored to accommodate these adverse conditions and special considerations will be required for the maintenance of the wetland during dry periods.

Figure 11-P2-3 Pond/Wetland System



Source: Adapted from NYDEC, 2001.

Conveyance

Stormwater should be conveyed to and from all stormwater management practices safely and to minimize erosion potential.

Inlet Protection

- *The number of inlets should be minimized, and one inlet is preferable. The inlet should be located at the most hydraulically remote point from the outlet, but in any case should be located in a manner that meets or exceeds desired length to width ratios.*
- *Inlet areas should be stabilized to ensure that non-erosive conditions exist for the design storm event.*
- *The ideal inlet discharge configuration is above the permanent pool to prevent potential hydraulic impacts from freezing.*

Oulet Protection

- *The channel immediately below an outfall should be modified to prevent erosion and conform to natural topography by use of a plunge pool or a riprap pad and sized for peak discharge velocities.*
- *Outlet protection should be used to reduce flow to non-erosive velocities from the principal spillway based on actual cover and soil conditions (3.5 to 5.0 ft/s).*
- *If a pond outlet discharges to a perennial stream or channel with dry weather base flow, tree clearing should be minimized and a forested riparian zone re-established.*
- *To convey potential flood flows from the basin, an armored emergency spillway should be provided.*

Wetland Liners

When the permanent pool does not intercept groundwater, a liner may be needed to maintain minimum water levels. Liners are also necessary for wetland systems that may present a risk to groundwater quality. **Table 11-P2-2** lists recommended specifications for clay and geomembrane liners.

Pool Benches

These specifications apply to permanent pools at the sediment forebay and micropool.

- *For side slopes steeper than 4:1, provide a 10-foot wide flat safety bench above the permanent pool level.*

Vegetation

High pollutant removal efficiencies are dependent on a dense cover of emergent plant vegetation. Actual plant species do not appear to be as important as plant growth habitat. In particular, use plants that have high colonization and growth rates, can establish large surface areas that continue through the winter dormant season, have high potential for treating pollutants, and are very robust in flooded environments. **Appendix A** contains planting guidance for stormwater wetlands. Other landscaping criteria include the following:

- *Soils should be modified to mitigate compaction that occurs during construction around the proposed planting sites.*
- *Woody vegetation may not be planted or allowed to grow within 25 feet of the toe of the embankment and 25 feet from the principal spillway structure.*
- *Existing trees should be preserved in the buffer area during construction. It is desirable to locate forest conservation areas adjacent to ponds and wetlands. To help discourage resident geese populations, the buffer can be planted with trees, shrubs, and native ground covers.*
- *Annual mowing of the pond/wetland buffer is only required along maintenance rights-of-way and the embankment. The remaining buffer can be managed as a meadow (mowing every other year) or forest.*

Maintenance Reduction Features

In addition to regular maintenance activities needed to maintain the function of stormwater practices, some design features can be incorporated to ease the maintenance burden of each practice. In constructed wetlands, maintenance reduction features include techniques to reduce the amount of required maintenance, as well as techniques to make regular maintenance activities easier.

- *Outlets should be designed with non-clogging features, such as a weir, or by incorporating trash racks for culverts and orifice openings.*
- *To prevent clogging from ice or floatables, a reverse slope outlet pipe can be used to draw water from below the permanent pool up to the outlet structure. The invert of the pipe drawing from the pool should be at least 18 inches from the bottom to prevent sediment discharge.*
- *Orifices should be no smaller than 6 inches in diameter, and have a trash rack to prevent clogging.*

Table 11-P2-2 Stormwater Wetland Liner Specifications

Linear Material	Property	Recommended Specifications
Clay	Minimum Thickness	6 to 12 inches
	Permeability	1×10^{-5} cm/sec[1]
	Particle Size	Minimum 15% passing #200 sieve[1]
Geomembrane	Minimum Thickness	30 mils (0.03 inches)
	Material	Ultraviolet resistant, impermeable poly-liner

Source: [1]NYDEC, 2001; all other listed specifications from City of Austin in Washington, 2000 (in Metropolitan Council, 2001).

- *Pools should have a manually operated drain to draw down the pond for infrequent maintenance or dredging of the main cell of the pond.*
- *Metal components of outlet structures should be corrosion resistant, but not galvanized due to the contribution of zinc to water (Washington, 2000).*
- *Outlet structures should be resistant to frost heave and ice action in the pond.*

Cold Climate Design Considerations

The following design elements should be considered to minimize potential performance impacts caused by cold weather:

- *Inlet pipes should not be submerged, since this can result in freezing and upstream damage or flooding.*
- *Bury pipes below the frost line to prevent frost heave and pipe freezing.*
- *To prevent standing water in the pipe and to reduce the potential for ice formation, increase the slope of inlet pipes to a minimum of 1 percent, if site conditions allow.*
- *If perforated riser pipes are used, the minimum orifice diameter should be 0.5 inches. In addition, the pipe should have a diameter of at least 6 inches.*
- *When a standard weir is used, the minimum slot width should be 3 inches, especially when the slot is tall.*
- *Baffle weirs can prevent ice formation near the outlet by preventing surface ice from blocking the inlet, encouraging the movement of base flow through the system.*
- *Riser hoods and reverse slope pipes should draw from at least 6 inches below the typical ice layer. This design encourages circulation in the pond, preventing stratification and formation of ice at the outlet. Reverse slope pipes should not be used for off-line ponds.*
- *Trash racks should be installed at a shallow angle to prevent ice formation.*
- *Additional storage should be provided to account for storage lost to ice buildup, especially in shallow wetlands where much of the pool becomes frozen. Ice thickness may be estimated by consulting with local authorities (the fire department, for example) with knowledge of the typical ice thickness in the area.*

Construction

- *Any stormwater treatment practices that create an embankment, including stormwater wetlands, are under the jurisdiction of the Dam Safety Section of the Connecticut DEP Inland Water Resources Division (IWRD) and should be constructed, inspected, and maintained in accordance with CGS §§22a-401 through 22a-411, inclusive, and applicable DEP guidance.*
- *Avoid soil compaction to promote growth of vegetation.*
- *Temporary erosion and sediment controls should be used during construction, and sediment deposited in the wetlands should be removed after construction, but preferably before wetland vegetation is planted.*
- *Temporary dewatering may be required if excavation extends below the water table. Appropriate sedimentation controls will be required for any dewatering discharges.*

- *Establishment of wetland plantings is critical. As a result, installation should be as directed by a biologist or landscape architect.*

Inspection and Maintenance

- *Plans for stormwater wetlands should identify detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance.*
- *The principal spillway should be equipped with a removable trash rack, and generally accessible from dry land.*
- *Sediment removal in the forebay and micropool should occur at a minimum of every five years or before the sediment storage capacity has been filled.*
- *Sediment removed should be disposed of according to an approved comprehensive operation and maintenance plan.*
- *Inspect twice per year for the first three years to evaluate plant sustainability, water levels, slope stability, and the outlet structure.*
- *Perform maintenance outside of vegetative growing and wildlife seasons.*
- *Harvesting of dead plant material is not required except in cases where high pollutant removal efficiencies, especially for nutrients, are required.*

Maintenance Access

- *A maintenance right of way or easement should extend to the wetland from a public road.*
- *Maintenance access should be at least 12 feet wide, have a maximum slope of no more than 15 percent, and be appropriately stabilized to withstand maintenance equipment and vehicles.*
- *The maintenance access should extend to the forebay, safety bench, riser, and outlet and be designed to allow vehicles to turn around.*

Non-clogging Low Flow Orifice

- *A low flow orifice shall be provided, with the size of the orifice sufficient to ensure that no clogging will occur.*
- *The low flow orifice should be adequately protected from clogging by either an acceptable external trash rack (recommended minimum orifice of 6 inches) or by internal orifice protection that may allow for smaller diameters (minimum of 1 inch).*
- *The preferred method is a submerged reverse-slope pipe that extends downward from the riser to an inflow point one foot below the normal pool elevation.*
- *Alternative methods are to employ a broad crested rectangular, V-notch, or proportional weir, protected by a half-round pipe that extends at least 12 inches below the normal pool level.*
- *The use of horizontally extended perforated pipe protected by geotextile fabric and gravel is not recommended. Vertical pipes may be used as an alternative if a permanent pool is present.*

Riser in Embankment

- *The riser must be located within the embankment for maintenance access, safety, and aesthetics.*
- *Lockable manhole covers, and manhole steps within easy reach of valves and other controls should provide access to the riser. The principal spillway opening should be "fenced" with pipe at 8-inch intervals for safety purposes.*

Drain

- *Except where local slopes prohibit this design, each wetland should have a drain pipe that can completely or partially drain the wetland. The drain pipe shall have an elbow or protected intake within the pond to prevent sediment deposition, and a diameter capable of draining the pond within 24 hours.*
- *Care should be exercised during pond draining to prevent rapid drawdown and minimize downstream discharge of sediments or anoxic water. The approving jurisdiction must be notified before draining a pond.*

Table 11-P2-3 Typical Maintenance Activities for Stormwater Wetlands

Activity	Schedule
❍ If necessary, re-plant wetland vegetation to maintain at least 50% surface area coverage in wetland plants after the second growing season.	One-time
❍ Inspect for invasive vegetation and remove where possible.	Semi-annual inspection
❍ Inspect for damage to the embankment and inlet/outlet structures. Repair as necessary. ❍ Note signs of hydrocarbon build-up, and deal with appropriately. ❍ Monitor for sediment accumulation in the facility and forebay. ❍ Examine to ensure that inlet and outlet devices are free of debris and are operational.	Annual inspection
❍ Repair undercut or eroded areas.	As needed maintenance
❍ Clean and remove debris from inlet and outlet structures. ❍ Mow side slopes.	Frequent (3-4 times/year) maintenance
❍ Harvest wetland plants that have been "choked out" by sediment build-up. ❍ Supplement wetland plants if significant portions have not established (at least 50% of the surface area) or have been choked out.	Annual maintenance (if needed)
❍ Remove sediment from the forebay.	5 to 7 year maintenance
❍ Monitor sediment accumulations, and remove sediment when the pool volume has become reduced significantly, plants are "choked" with sediment, or the wetland becomes eutrophic.	20 to 50 year maintenance

Source: WMI, 1997.

Cost Considerations

Stormwater wetlands are relatively inexpensive stormwater treatment practices, but vary widely depending on the complexity of the design or site constraints. The costs of stormwater wetlands are generally 25 percent more expensive than stormwater ponds of an equivalent volume and may be estimated using the following equation (Brown and Schueler, 1997):

$$C = 30.6V^{0.705}$$

where: C = Construction, design, and permitting cost.

V = Wetland volume needed to control the 10-year storm (ft^3).

Results should be modified for inflation to reflect current costs. The annual cost of routine maintenance is typically estimated at approximately 3 to 5 percent of the construction cost (EPA Storm Water Wetland Fact Sheet, http://www.epa.gov/npdes/menuofbmps/menu.htm). Stormwater wetlands typically have a design life longer than twenty years.

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Infiltration Practices

Source: Nonpoint Education for Municipal Officials (NEMO).

Treatment Practice Type

Primary Treatment Practice ●
Secondary Treatment Practice

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Significant Benefit
Phosphorus	Significant Benefit
Nitrogen	Significant Benefit
Metals	Significant Benefit
Pathogens	Partial Benefit
Floatables*	Partial Benefit
Oil and Grease*	Partial Benefit
Dissolved Pollutants	Partial Benefit
Runoff Volume Reduction	
Runoff Capture	Significant Benefit
Groundwater Recharge	Significant Benefit
Stream Channel Protection	Partial Benefit
Peak Flow Control	Partial Benefit

Key: ■ Significant Benefit
■ Partial Benefit
□ Low or Unknown Benefit

*Only if a skimmer is incorporated

Implementation Requirements

Cost ....Moderate
Maintenance..................................High

Description

Stormwater infiltration practices are designed to capture stormwater runoff and infiltrate it into the ground over a period of days. This section includes two types of infiltration practices:

- *Infiltration Trench*
- *Infiltration Basin*

Infiltration practices reduce runoff volume, remove fine sediment and associated pollutants, recharge groundwater, and provide partial attenuation of peak flows for storm events equal to or less than the design storm. Infiltration practices are appropriate for small drainage areas, but can also be used for larger multiple lot applications, in contrast to rain gardens and dry wells, which are primarily intended for single lots.

Infiltration trenches are shallow, excavated, stone-filled trenches in which stormwater is collected and infiltrated into the ground. Infiltration trenches can be constructed at a ground surface depression to intercept overland flow or can receive piped runoff discharged directly into the trench. Runoff gradually percolates through the bottom and sides of the trench, removing pollutants through sorption, trapping, straining, and bacterial degradation or transformation.

Infiltration basins are stormwater impoundments designed to capture and infiltrate the water quality volume over several days, but do not retain a permanent pool. Infiltration basins can be designed as off-line devices to infiltrate the water quality volume and bypass larger flows to downstream flood control facilities or as combined infiltration/flood control facilities by providing detention above the infiltration zone. This section describes off-line basins designed for groundwater recharge and stormwater quality control, rather than for flood control. The bottom of an infiltration basin typically contains vegetation to increase the infiltration capacity of the basin, allow for vegetative uptake, and reduce soil erosion and scouring of the basin.

A number of underground infiltration structures, including premanufactured pipes, vaults, and modular structures, have been developed in recent years as alternatives to infiltration trenches and basins for space-limited sites and stormwater retrofit applications. Performance of these systems varies by manufacturer and system design. These systems are currently considered secondary treatment practices due to limited field performance data, although pollutant removal efficiency is anticipated to be similar to that of infiltration trenches and basins.

Infiltration practices are susceptible to clogging by suspended solids in stormwater runoff. Therefore, infiltration trenches and basins require pretreatment to remove a portion of the solids load before entering the infiltration practice. Infiltration trenches and basins are often preceded by other primary or secondary treatment practices that are effective in removing coarse solids, as well as oil, grease, and floatable organic and inorganic material. Infiltration practices are not appropriate in areas that contribute high concentrations of sediment, hydrocarbons, or other floatables without adequate pretreatment.

Because infiltration practices recharge stormwater directly to groundwater, they can potentially contaminate groundwater supplies with dissolved pollutants contained in stormwater runoff or mobilized from subsurface contamination. Runoff sources that cause particular problems for infiltration structures include sites with high pesticide levels; manufacturing and industrial sites, due to potentially high concentrations of soluble toxicants and heavy metals; and snowmelt runoff because of salts. Infiltration practices should be carefully sited and designed to minimize the risk of groundwater contamination. Runoff from residential areas (rooftops and lawns) is generally considered the least polluted and, therefore, the safest runoff for discharge to infiltration structures (Wisconsin DNR, 2000).

Advantages

- *Promote groundwater recharge and baseflow in nearby streams.*
- *Reduce the volume of runoff, thereby reducing the size and cost of downstream drainage and stormwater control facilities.*
- *Provide partial attenuation of peak flows, thereby reducing local flooding and maintaining streambank integrity.*
- *Appropriate for small or space-limited sites.*

Limitations

- *Potential failure due to improper siting, design (including inadequate pretreatment), construction, and maintenance. Infiltration basins usually fail for one or more of the following reasons (Wisconsin DNR, 2000):*
  - *Premature clogging*
  - *A design infiltration rate greater than the actual infiltration rate*
  - *Because the basin was first used for site construction erosion control*
  - *Soil was compacted during construction*
  - *The upland soils or basin walls were not stabilized with vegetation, and sediment was delivered to the basin*
- *Potential for mosquito breeding due to standing water in the event of system failure.*
- *Risk of groundwater contamination depending on subsurface conditions, land use, and aquifer susceptibility.*
- *Require frequent inspection and maintenance.*
- *Not suitable for stormwater runoff from land uses or activities with the potential for high sediment or pollutant loads without pretreatment sized to treat the entire water quality volume.*
- *Low removal of dissolved pollutants in very coarse soils.*
- *Use generally restricted to small drainage areas.*
- *Significantly reduced performance in the winter due to frozen soils.*
- *Failure is not readily apparent until the system is severely compromised.*
- *Visual inspection alone may not detect problems.*

Siting Considerations

Drainage Area: The maximum contributing drainage area for infiltration trenches should not exceed 5 acres (2 acres is recommended). The maximum contributing drainage area for infiltration basins should not exceed 25 acres (10 acres is recommended). While theoretically feasible, provided soils are sufficiently permeable, infiltration from larger contributing drainage areas can lead to problems such as groundwater mounding, clogging, and compaction.

Soils: Underlying soils should have a minimum infiltration rate of 0.3 inches per hour, as initially determined from NRCS soil textural classifications.

Table 11-P3-1 Minimum Infiltration Rates of NRCS Hydrologic Soil Groups

Group	Soil Texture	Minimum Infiltration Rate (in/hr)
A	Sand, loamy sand, or sandy loam	0.30 – 0.45
B	Silt loam or loam	0.15 – 0.30
C	Sandy clay loam	0.05 – 0.15
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay	0 – 0.05

Note: Tabulated infiltration rates are approximately equal to saturated hydraulic conductivities.
Source: U.S. Soil Conservation Service, 1986.

(**Table 11-P3-1**), and subsequently confirmed by a field investigation acceptable to the review authority. Soils should generally have a clay content of less than 30 percent and a silt/clay content of less than 40 percent. Suitable soils generally include sand, loamy sand, sandy loam, loam, and silt loam. Recommended soil investigation procedures include:

- *Infiltration rates can be determined through an appropriate field permeability test.*
- *Infiltration rates should be reduced by a safety factor to account for clogging over time. The recommended design infiltration rate is equal to one-half the field-measured infiltration rate (i.e., safety factor of 2).*
- *Test pits or soil borings should be used to determine depth to groundwater, depth to bedrock (if within 4 feet of proposed bottom of infiltration structure), and soil type.*
- *Test pits or soil borings should be excavated or dug to a depth of 4 feet below the proposed bottom of the facility.*
- *Infiltration tests, soil borings, or test pits should be located at the proposed infiltration facility to identify localized soil conditions.*
- *Testing should be performed by a qualified professional registered in the State of Connecticut. (licensed Professional Engineer, Professional Geologist, or Certified Soil Scientist).*
- *For infiltration trenches, one field test and one test pit or soil boring should be performed per 50 linear feet of trench. A minimum of two field tests and test pits or soil borings should be taken at each trench. The design should be based on the slowest rate obtained from the infiltration tests performed at the site.*
- *For infiltration basins, one field test and one test pit or soil boring should be performed per 5,000 square feet of basin area. A minimum of three field tests and test pits or soil borings should be performed at each basin. The design of the basin should be based on the slowest rate obtained from the field tests performed at the site.*

Land Use: Infiltration practices should not be used to infiltrate runoff containing significant concentrations of soluble pollutants that could contaminate groundwater, without adequate pretreatment. Land uses or activities that typically generate stormwater with higher pollutant loads are identified in Chapter Seven. Infiltration practices should not be used in areas of existing subsurface contamination, and may be prohibited or restricted within aquifer protection areas or wellhead protection areas at the discretion of the review authority.

Slopes: Infiltration basins are not recommended in areas with natural slopes greater than 15 percent, and should be located at least 50 feet from slopes greater than 15 percent, since steep slopes can cause water leakage in the lower portions of the basin and may reduce infiltration rates due to lateral water movement.

Water Table: The bottom of the infiltration facility should be located at least 3 feet above the seasonally high water table or bedrock, as documented by on-site soil testing.

Miscellaneous: Infiltration practices should not be placed over fill materials and, except where recommended by local or state health departments or by the Department of Environmental Protection, should be located at least 75 feet away from:

- *Drinking water supply wells*
- *Septic systems (any components)*
- *Surface water bodies*
- *Building foundations (at least 100 feet upgradient and at least 25 feet downgradient from building foundations)*

Design Criteria

Design considerations for infiltration trenches and basins are presented below and summarized in **Table 11-P3-2.**

Infiltration Trench

Figure 11-P3-1 depicts a typical schematic design of an infiltration trench. Two infiltration trench designs commonly used for parking lots are shown in **Figure 11-P3-2.**

Design Volume

- *Infiltration trenches should be designed to infiltrate the entire water quality volume through the bottom of the trench (sides are not considered in sizing).*
- *Infiltration trenches should be designed as off-line practices.*

Pretreatment

- *Pretreatment should be provided to accommodate 25 percent of the water quality volume. Pretreatment generally consists of a sediment forebay or other device designed to capture coarse particulate pollutants, floatables, and oil and grease (if necessary). Pretreatment is required for soils with infiltration rates over 3.0 inches per hour.*
- *A vegetative buffer around the trench is recommended to intercept surface runoff and prolong the life of the structure.*

Draining Time

- *Infiltration trenches should be designed to completely drain the water quality volume into the soil within 48 to 72 hours after the storm event. Infiltration trenches should completely dewater between storms.*
- *A minimum draining time of 12 hours is recommended to ensure adequate pollutant removal.*

Infiltration Rate

- *A minimum field-measured soil infiltration rate of 0.3 inches per hour is recommended as a practical lower limit for the feasibility of infiltration practices. Lower infiltration rates may be acceptable provided that the water quality volume and drain time criteria can be met. Field-measured soil infiltration rates should not exceed 5.0 inches per hour.*

Trench Surface Area and Depth

- *The bottom area of the trench should be sized to allow for infiltration of the entire water quality volume within 48 hours. The trench bottom area can be calculated using the following equation (Metropolitan Council, 2001):*

$$A = \frac{12WQV}{Pnt}$$

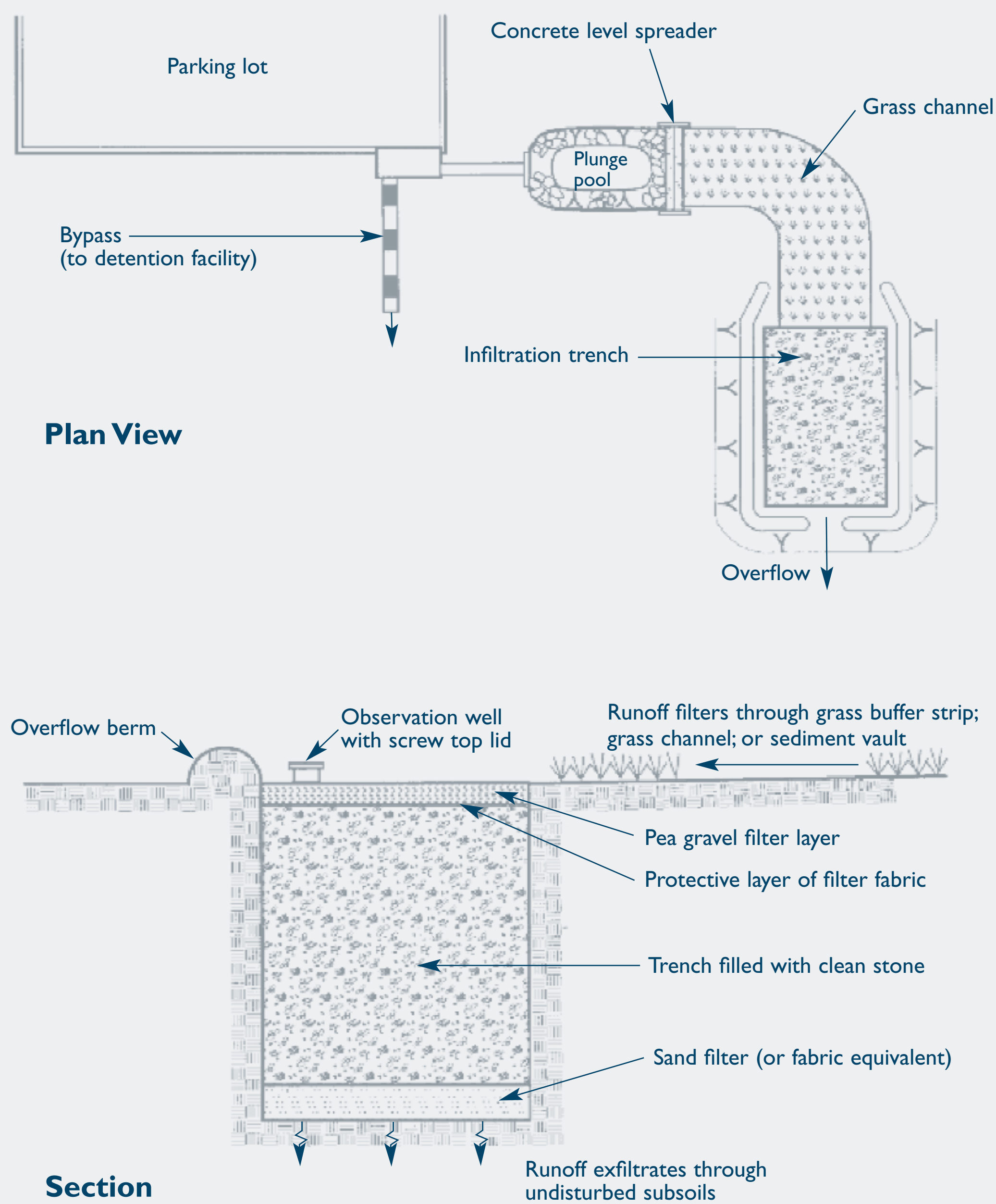
where:
- A = effective bottom area of trench (ft^2)
- WQV = water quality volume (ft^3)
- P = design infiltration rate of soil (in/hr) (one-half the minimum field measured infiltration rate)
- n = porosity of storage media (0.4 for 1.5- to 3-inch diameter clean washed stone)
- t = maximum drain time (48 hours)

- *The trench should be sized to hold the entire water quality volume. Therefore, the length of the trench should be determined based on the water quality volume and the calculated effective bottom area.*

Storage Media

- *The trench should be filled with clean, washed aggregate with a diameter of 1.5 to 3 inches (porosity of 40 percent). The surface of the trench should be lined with permeable filter fabric and additional washed pea gravel or similar aggregate to improve sediment filtering in the top of the trench.*
- *The sides of the trench should be lined with filter fabric. The filter fabric should be compatible with the soil textures and application. The bottom of the trench can be lined with filter fabric or 6 to 12 inches of clean sand. Clean sand is preferred over filter fabric since clogging can occur at the*

Figure 11-P3-1 Infiltration Trench



Source: Adapted from Center for Watershed Protection, 2000.

Table 11-P3-2 Design Criteria for Infiltration Practices	
Parameter	**Design Criteria**
Design Volume	Entire water quality volume (WQV)
Pretreatment Volume	25% of WQV
Maximum Draining Time	48 to 72 hours after storm event (entire WQV)
Minimum Draining Time	12 hours (for adequate pollutant removal)
Maximum Contributing Drainage Area	Trench: 5 acres (2 recommended) Basin: 25 acres (10 recommended)
Minimum Infiltration Rate	0.3 in/hr (as measured in the field), lower infiltration rates may be acceptable provided sufficient basin floor area is provided to meet the required WQV and drain time
Maximum Infiltration Rate	5.0 in/hr (as measured in the field); pretreatment required for infiltration rates over 3.0 in/hr
Depth	Trench: 2 to 10 feet (trench depth) Basin: 3 feet (ponding depth) recommended, unless used as combined infiltration and flood control facilities

Source: Adapted from Wisconsin Department of Natural Resources, 2000; NYDEC, 2001; Metropolitan Council, 2001; MADEP, 1997; Lee et al., 1998.

filter fabric layer, and sand restricts downward flow less than fabric. Sand also encourages drainage and prevents compaction of the native soil while the stone aggregate is added.

- *An observation well should be installed along the trench centerline to monitor the water drainage in the system. The well should consist of a well-anchored, vertical perforated PVC pipe with a lockable aboveground cap (**Figure 11-P3-3**).*

Conveyance

- *Surface runoff exceeding the capacity of the trench should be conveyed in a stabilized channel if runoff velocities exceed erosive velocities (3.5 to 5.0 feet per second). If velocities do not exceed the non-erosive threshold, overflow may be accommodated by natural topography.*
- *Stormwater outfalls should be designed to convey the overflow associated with the 10-year design storm.*

Winter Operation

- *Infiltration trenches can be operated in the winter if the bottom of the trench is below the frost line.*
- *Freezing is less likely if a subsurface pipe carries runoff directly into the stone aggregate.*
- *Trenches covered with topsoil may not operate efficiently during the winter months because frozen soils tend to reduce infiltration.*

Infiltration Basin

Figure 11-P3-4 depicts a typical schematic design of an infiltration basin.

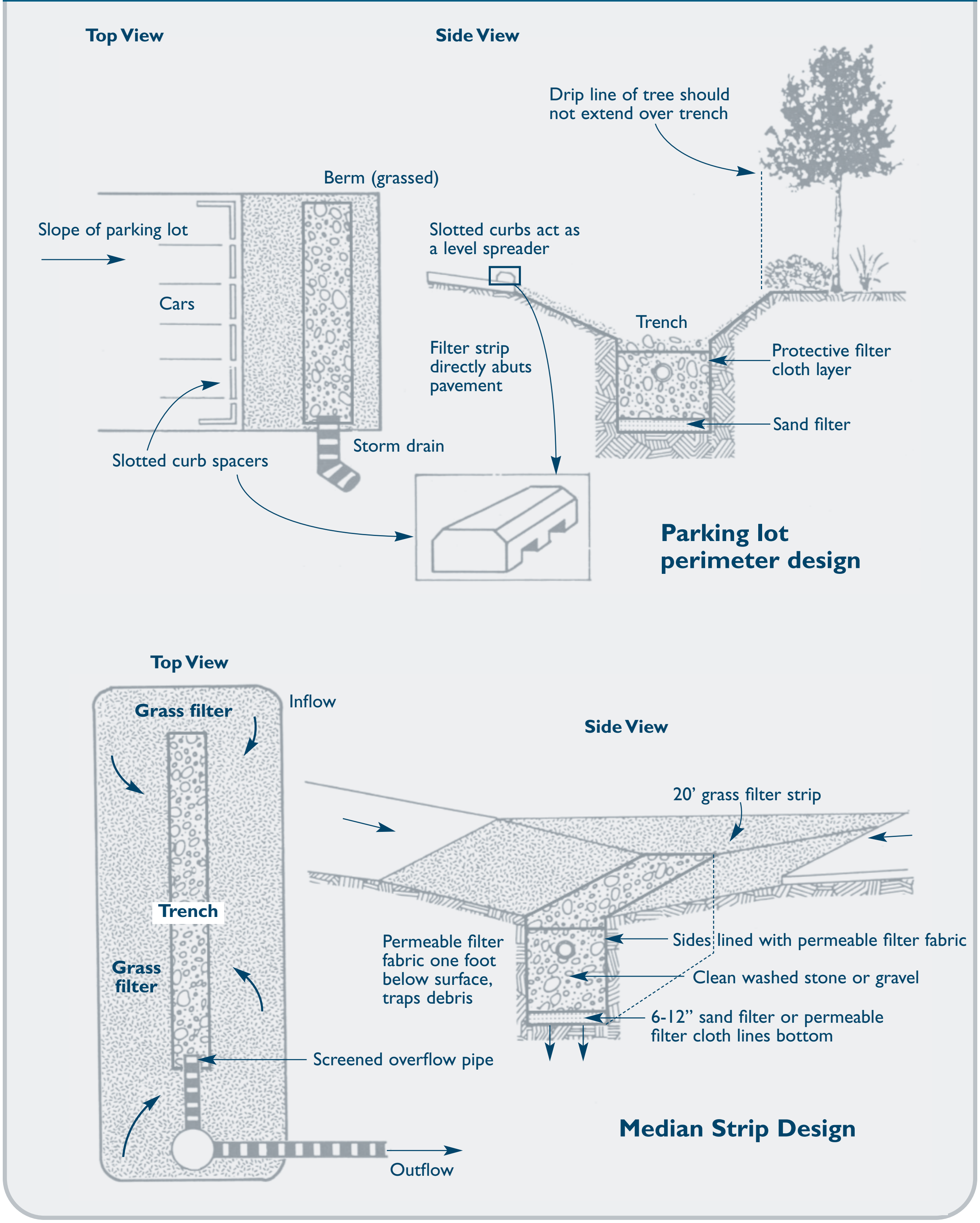
Design Volume

- *Infiltration basins should be designed to infiltrate the entire water quality volume through the bottom of the basin.*
- *Infiltration basins should generally be designed as off-line practices, unless used as combined infiltration and flood control facilities or where retention of runoff from storms larger than the water quality design storm is required (e.g., discharges within 500 feet of tidal wetlands to meet runoff capture criterion).*

Pretreatment

- *Pretreatment should be provided to accommodate 25 percent of the water quality volume. Pretreatment generally consists of a sediment forebay or other device designed to capture coarse particulate pollutants, floatables, and oil and grease (if necessary). Pretreatment is required for soils with infiltration rates over 3.0 inches per hour.*

Figure 11-P3-2 Infiltration Trench Designs for Parking Lots



Source: Adapted from Schueler, 1987.

Draining Time

- *Infiltration basins should be designed to completely drain the water quality volume into the soil within 48 to 72 hours after the storm event. Infiltration basins should completely dewater between storms.*
- *A minimum draining time of 12 hours is recommended to ensure adequate pollutant removal.*

Infiltration Rate

- *A minimum field-measured soil infiltration rate of 0.3 inches per hour is recommended as a practical lower limit for the feasibility of infiltration practices. Lower infiltration rates may be acceptable provided that the water quality volume and drain time criteria can be met. Field-measured soil infiltration rates should not exceed 5.0 inches per hour.*

Basin Dimensions and Configuration

- *The basin dimensions can be determined from the required storage volume and maximum depth of the basin. The required storage volume is equal to the water quality volume plus precipitation that falls within the basin during the water quality design storm:*

$$V = WQV + (P)(A_b)$$

where: D = required basin storage volume
P = design water quality volume
t = design precipitation = 1 inch
A_b = basin surface area

This equation conservatively assumes no infiltration during the water quality design storm. The depth of water in off-line infiltration basins should not exceed 3 feet for safety considerations. Larger depths may be required for combined infiltration/flood control basins. The maximum basin depth can be calculated from the following equation:

$$D = Pt$$

where: D = maximum basin depth (in)
P = design infiltration rate of soil (in/hr) (one-half the minimum field measured infiltration rate)
t = maximum drain or ponding time (48 hours)

- *The length and width of the basin can be calculated from the water depth and required basin storage volume, as shown above.*
- *The basin shape can be any configuration that blends with the surrounding landscape.*
- *The floor of the basin should be graded as flat as possible for uniform ponding and infiltration.*
- *The basin side slopes should be no steeper than 3:1 (horizontal:vertical). Flatter side slopes are preferred for vegetative stabilization, easier mowing and maintenance access, and safety.*
- *Infiltration basins may be equipped with an underdrain system for dewatering when the systems become clogged.*

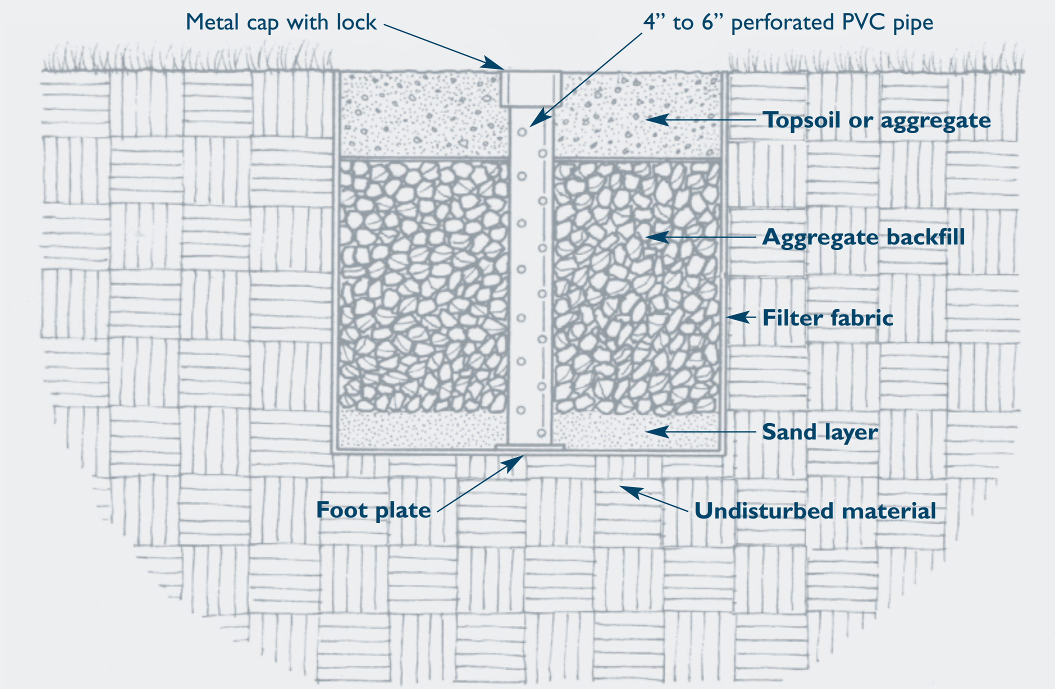
Conveyance

- *Inlet channels to the basin should be stabilized to mitigate against erosive velocities. Riprap used for this purpose should be designed to spread flow uniformly over the basin floor.*
- *A bypass flow path or pipe should be incorporated into the design of the basin to convey high flows around the basin via an upstream flow splitter.*
- *Stormwater bypass conveyances should be designed to convey the overflow associated with the 10-year design storm.*
- *Infiltration basins should be equipped with an emergency spillway capable of passing runoff from large storms without damage to the impoundment. The overflow should be conveyed in a stabilized channel if runoff velocities exceed erosive velocities (3.5 to 5.0 feet per second). If velocities do not exceed the non-erosive threshold, overflow may be accommodated by natural topography.*

Vegetation

- *Vegetative buffers are recommended around the perimeter of the basin for erosion control and additional sediment filtering.*
- *The bottom and side slopes of the basin should be planted with a dense stand of water-tolerant grass. Plant roots enhance the pore space and infiltration in the underlying soil. Use of low-maintenance, rapidly germinating grasses is recommended. Plants should be able to withstand prolonged periods of wet and dry*

Figure 11-P3-3 Observation Well Detail



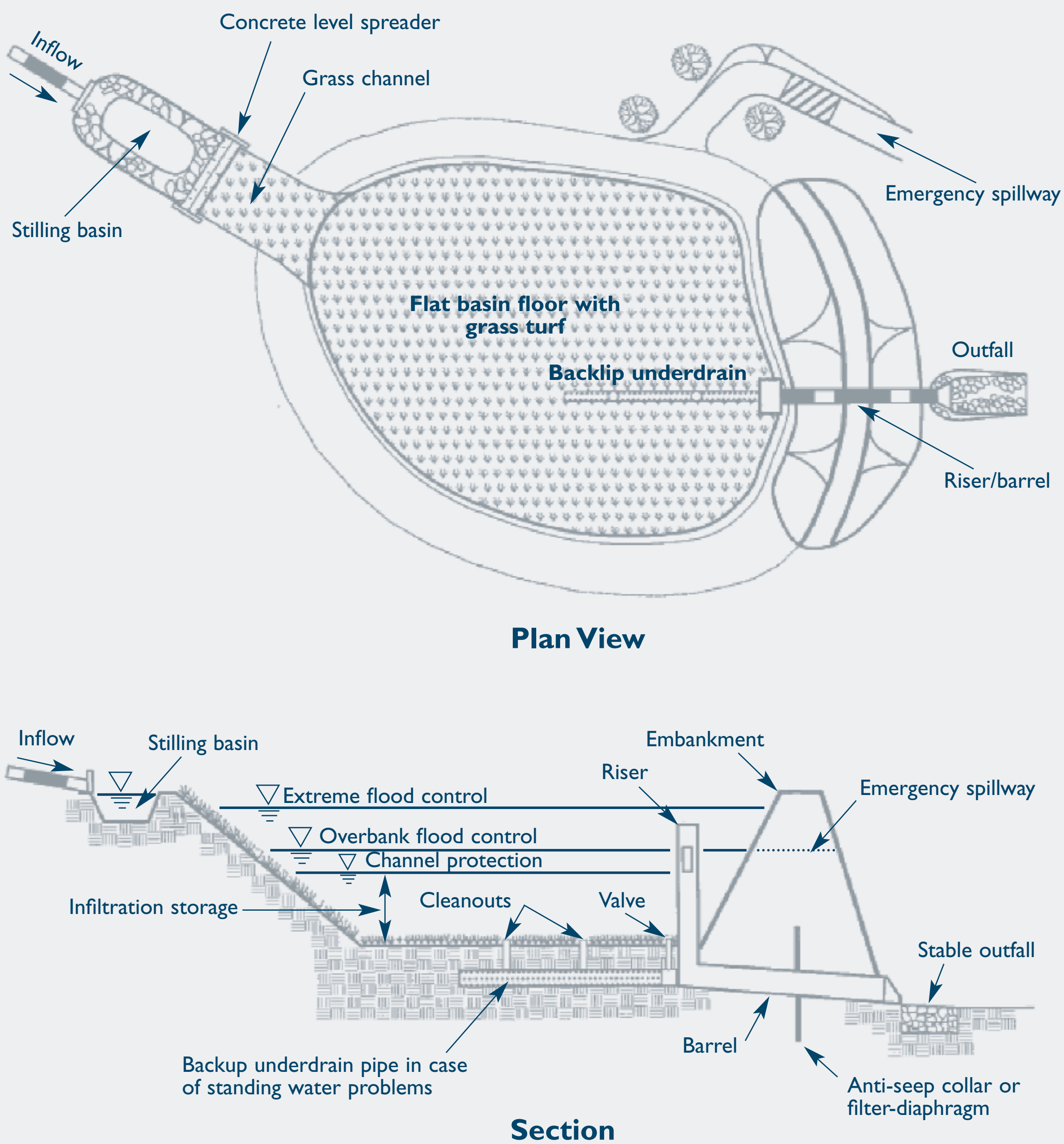
Source: Wisconsin DNR, 2000.

conditions. Highly invasive plants are not recommended. Recommended plant species generally include those species appropriate for hydrologic zones 3 and 4 in ***Table A-1 of Appendix A.*** *Loose stone, riprap, or other materials requiring hand removal of debris should not be used on the basin floor.*

Construction

- *Any stormwater treatment practices that create an embankment, including stormwater infiltration basins, are under the jurisdiction of the Dam Safety Section of the Connecticut DEP Inland Water Resources Division (IWRD) and should be constructed, inspected, and maintained in accordance with CGS §§ 22a-401 through 22a-411, inclusive, and applicable DEP guidance.*
- *Proper construction of infiltration practices is critical to minimize the risk of premature failure.*
- *Infiltration practices should not be used as temporary sediment basins during construction.*
- *Infiltration practices should be constructed at or near the end of the development construction. The development plan sheets should list the proper construction sequence so that the infiltration structure is protected during construction.*
- *Before the development site is graded, the area of the infiltration practices should be roped off and flagged to prevent soil compaction by heavy equipment.*
- *Light earth-moving equipment (backhoes or wheel and ladder type trenchers) should be used to excavate infiltration practices. Heavy equipment can cause soil compaction and reduce infiltration capacity. Compaction of the infiltration area and surrounding soils during construction should be avoided.*
- *Smearing of soil at the interface of the basin or trench floor and sides should be avoided.*
- *The sides and bottom of an infiltration trench should be raked or scarified after the trench is excavated to restore infiltration rates.*
- *The floor of an infiltration basin should be raked or deep tilled after final grading to restore infiltration rates.*

Figure 11-P3-4 Infiltration Basin



Source: Wisconsin DNR, 2000.

- *Appropriate erosion and sediment controls should be utilized during construction, as well as immediately following construction, to stabilize the soils in and around the basin.*

Inspection and Maintenance

- *Plans for infiltration practices should identify detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance.*
- *Pretreatment devices should be inspected and cleaned at least twice a year.*
- *For the first few months after construction, infiltration trenches and basins should be inspected after every major storm. Inspections should focus on the duration of standing water in a basin or in the observation well of a trench after a storm. Ponding water after 48 hours indicates that the bottom of the infiltration structure may be clogged. If the bottom of the trench becomes clogged, all of the stone aggregate and filter fabric must be removed and replaced with new material. The bottom of the trench may need to be tilled to enhance infiltration. Water ponded at the surface of a trench may indicate only surface clogging.*
- *After the first few months of operation, maintenance schedules for infiltration practices should be based on field observations, although inspections should be performed at least twice per year. For infiltration trenches, observations should include checking for accumulated sediment, leaves and debris in the pretreatment device, clogging of inlet and outlet pipes, and ponded water inside and on the surface of the trench. For infiltration basins, observations should include measurement of differential accumulation of sediment, erosion of the basin floor, health of the basin vegetation, and condition of riprap.*
- *Grass clippings, leaves, and accumulated sediment should be removed routinely from the surface of infiltration trenches. The upper layer of stone and filter fabric may need to be replaced to repair surface clogging.*
- *Sediment should be removed from infiltration basins when the sediment is dry (visible cracks) and readily separates from the floor of the basin to minimize smearing the basin floor. The remaining soil should be tilled and revegetated.*
- *The grass in the basin, side slopes, and buffer areas should be mowed, and grass clippings and accumulated trash removed at least twice during the growing season. Mowing should not be performed when the ground is soft to avoid the creation of ruts and compaction, which can reduce infiltration.*

Cost Considerations

Costs for implementation of infiltration practices are highly variable from site to site depending on soil conditions and the required pretreatment. Typical installation costs for infiltration trenches and basins are approximately $5.00 and $2.00 per cubic foot (adjusted for inflation) of stormwater treated (SWRPC, 1999), respectively. The cost per impervious acre treated varies by region and design variant. Infiltration basins are relatively cost-effective practices because little infrastructure is needed. Infiltration basins typically consume about 2 to 3 percent of the site draining to them. Maintenance costs for infiltration basins are estimated at 5 to 10 percent of construction costs, while maintenance costs for infiltration trenches are estimated at 20 percent of construction costs (EPA, 2002). Infiltration trenches are more expensive to construct than some other treatment practices in terms of cost per volume of stormwater treated. Because infiltration practices have high failure rates if improperly designed, constructed, and maintained, these practices may require frequent replacement, which would reduce their overall cost effectiveness.

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Filtering Practices

Source: Nonpoint Education for Municipal Officials (NEMO).

Treatment Practice Type

Primary Treatment Practice	●
Secondary Treatment Practice	

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Significant Benefit
Phosphorus	Significant Benefit
Nitrogen	Significant Benefit
Metals	Significant Benefit
Pathogens	Significant Benefit
Floatables*	Partial Benefit
Oil and Grease*	Significant Benefit
Dissolved Pollutants	Partial Benefit
Runoff Volume Reduction	
Runoff Capture	Low or Unknown Benefit
Groundwater Recharge	Partial Benefit
Stream Channel Protection	Low or Unknown Benefit
Peak Flow Control	Low or Unknown Benefit

Key: ■ Significant Benefit; ■ Partial Benefit; □ Low or Unknown Benefit

*Only if a skimmer is incorporated

Implementation Requirements

Capital Cost....................................High

Maintenance Burden..................High

Description

Stormwater filtering practices capture and store stormwater runoff and pass it through a filtering media such as sand, organic material, or soil for pollutant removal. Stormwater filtering practices generally fall into two categories, which are described in this section:

- *Surface filters (including bioretention)*
- *Underground filters*

Stormwater filters are primarily water quality control devices designed to remove particulate pollutants and, to a lesser degree, bacteria and nutrients. A separate facility would typically be required to provide channel protection and peak flow control. Most filtering systems consist of four design components:

- *Inflow regulation to divert the water quality volume into the structure*
- *Pretreatment to capture coarse sediments*
- *Filter surface and media*
- *Outflow mechanism to return treated flows back to the conveyance system or into the soil*

Stormwater filtering practices are typically applied to small drainage areas (5 to 10 acres) and designed as off-line systems to treat the water quality volume and bypass larger flows. The water quality volume is diverted into a pretreatment settling chamber or forebay where coarse solids are allowed to settle, thereby reducing the amount of sediment that reaches the filter. Water flows to the filter surface in a controlled manner, where finer sediment and attached pollutants are trapped or strained out and microbial breakdown of pollutants (i.e., nitrification) can occur. Filtered stormwater is then collected below the filter bed or media and either returned to the conveyance system via an underdrain or allowed to infiltrate into the soil (i.e., exfiltration). Due to their similarity to infiltration basins, which were discussed in the previous section, exfiltration systems are not addressed in this section.

Stormwater filtering practices are commonly used to treat runoff from small sites such as parking lots and small developments; areas with high pollution potential such as industrial sites; or in highly urbanized areas where space is limited. A number of surface and underground stormwater filter design variations have been developed for these types of applications. Underground filters can be placed under parking lots and are well suited to highly urbanized areas or space-limited sites since they consume no surface space. As such, stormwater filters are often suitable for retrofit applications where space is typically limited. Stormwater filtration systems that do not discharge to the soil (i.e., are contained in a structure or equipped with an impermeable liner) are also suitable options for treating runoff from industrial areas and other land uses with high pollutant potential since the water is not allowed to infiltrate into the soil and potentially contaminate groundwater.

Design Variations

Surface Filters

Surface Sand Filter: The surface sand filter is the original sand filter design, in which both the filter bed and sedimentation chamber are aboveground. Surface sand filters can consist of excavated, earthen basins or aboveground concrete chambers (i.e., Austin Sand Filter). **Figure 11-P4-1** and **Figure 11-P4-2** depict schematics of two common surface sand filter designs.

Organic Filters: Organic filters are similar to surface sand filters, with the sand medium replaced with or supplemented by material having a higher organic content such as peat or compost. Organic filters are generally ineffective during the winter in cold climates because they retain water and consequently freeze solid and become completely impervious. Organic filters are not recommended for use in Connecticut and, therefore, are not addressed in this Manual.

Bioretention: Bioretention systems are shallow landscaped depressions designed to manage and treat stormwater runoff. Bioretention systems are a variation of a surface sand filter, where the sand filtration media is replaced with a planted soil bed designed to remove pollutants through physical and biological processes (EPA, 2002). Stormwater flows into the bioretention area, ponds on the surface, and gradually infiltrates into the soil bed. Treated water is allowed to infiltrate into the surrounding soils or is collected by an underdrain system and discharged to the storm sewer system or receiving waters. Small-scale bioretention applications (i.e., residential yards, median strips, parking lot islands), commonly referred to as rain gardens, are also described in Chapter Four of this Manual as a Low Impact Development design practice. **Figure 11-P4-3** depicts schematic designs of several common types of bioretention facilities.

Underground Filters

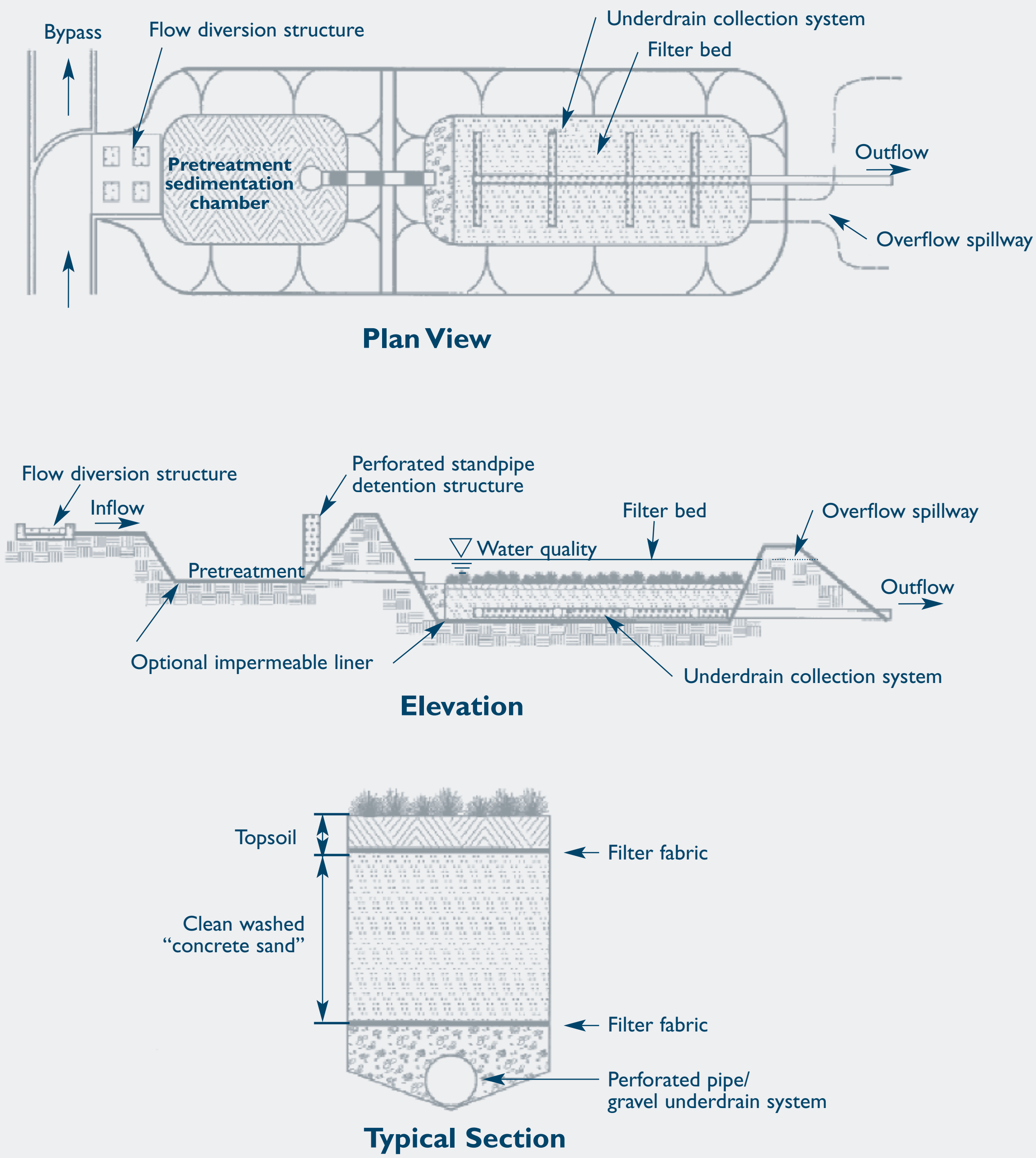
D.C. Sand Filter: This underground vaulted filter design was developed by the District of Columbia in the late 1980s. The D.C. Sand Filter includes three chambers. The first chamber and a portion of the second chamber contain a permanent pool of water, which provides sedimentation and removal of floatables and oil and grease. Water flows through a submerged opening near the dividing wall that connects the two chambers, into the second chamber and onto the filter bed. Filtered water is collected by an underdrain system and flows into the third chamber, which acts like a clearwell and overflow chamber (EPA, 2002). A schematic of the D.C. Sand Filter is shown in **Figure 11-P4-4.**

Perimeter Sand Filter: The perimeter sand filter is an underground vault sand filter that was originally developed in Delaware (also known as the "Delaware Sand Filter") for use around the perimeter of parking lots. The system contains two parallel chambers and a clearwell. Overland flow enters the first chamber through slotted grates, which acts as a sedimentation chamber. Water then flows over weirs into the second chamber, which contains the filter media. Filtered water is collected by an underdrain system and flows into a clearwell before discharging to the storm drain system. A schematic of a perimeter sand filter is shown in **Figure 11-P4-5.**

Alexandria Sand Filter: The Alexandria Sand Filter, developed in Alexandria, Virginia, is similar to the D.C. Sand Filter in that it consists of three distinct chambers: a sediment chamber, a filtering chamber, and a clearwell. However, the Alexandria design replaces the permanent pool oil/water separator with a gabion barrier that filters and dissipates energy. This variation is a dry system designed to drain between storms. **Figure 11-P4-6** shows a schematic of an Alexandria Sand Filter.

Proprietary Designs: A number of proprietary underground media filter designs have been developed in recent years. These systems consist of the

Figure 11-P4-1 Earthen Surface Sand Filter



Source: Adapted from Center for Watershed Protection, 2000.

same general configuration, with specialized filter media targeted at removal of various particulate and soluble pollutants. Most of these pre-manufactured systems consist of a sedimentation chamber and a filtration chamber that holds a series of canisters with replaceable/recyclable media cartridges. These systems currently are not considered primary treatment practices due to limited peer-reviewed data on their performance under field conditions. Proprietary filtering designs are discussed further as secondary treatment practices later in this chapter.

Advantages

- *Applicable to small drainage areas.*
- *Can be applied to most sites due to relatively few constraints and many design variations (i.e., highly versatile).*
- *May require less space than other treatment practices. Underground filters can be used where space limitations preclude surface filters.*
- *Ideal for stormwater retrofits and highly developed sites.*
- *High solids, metals, and bacteria removal efficiency.*
- *High longevity for sand filters.*
- *Bioretention can provide groundwater recharge.*

Limitations

- *Pretreatment required to prevent filter media from clogging.*
- *Limited to smaller drainage areas.*
- *Frequent maintenance required.*
- *Relatively expensive to construct.*
- *Typically require a minimum head difference of approximately 5 feet between the inlet and outlet of the filter.*
- *Surface sand filters not feasible in areas of high water tables.*
- *Should not be used in areas of heavy sediment loads (i.e., unstabilized construction sites).*
- *Provide little or no quantity control.*
- *Surface and perimeter filters may be susceptible to freezing.*
- *Surface filters can be unattractive without grass or vegetative cover. Bioretention may be a more aesthetically pleasing alternative due to incorporation of plants.*
- *May have odor and mosquito-breeding problems if not designed properly.*

Siting Considerations

Drainage Area: The maximum contributing drainage area for most surface and underground filtering practices is between 5 and 10 acres. Filtering practices can be used to treat runoff from larger drainage areas if properly designed, although the potential for clogging increases for drainage areas larger than 10 acres. Bioretention should be restricted to drainage areas of 5 acres or less.

Slopes and Head Requirements: Filtering systems can be used on sites with slopes of approximately 6 percent or less. Most stormwater filter designs require between 5 and 7 feet of head difference between the filter inlet and outlet to allow sufficient gravity flow through the system. Perimeter sand filters and bioretention areas require as little as 2 feet of head.

Soils: Stormwater filtering systems that return filtered runoff to the conveyance system and do not infiltrate into the ground can be used in almost any soil type. Bioretention designs that rely on infiltration can be used only when the soil infiltration characteristics are appropriate (see the Infiltration Practices section of this chapter).

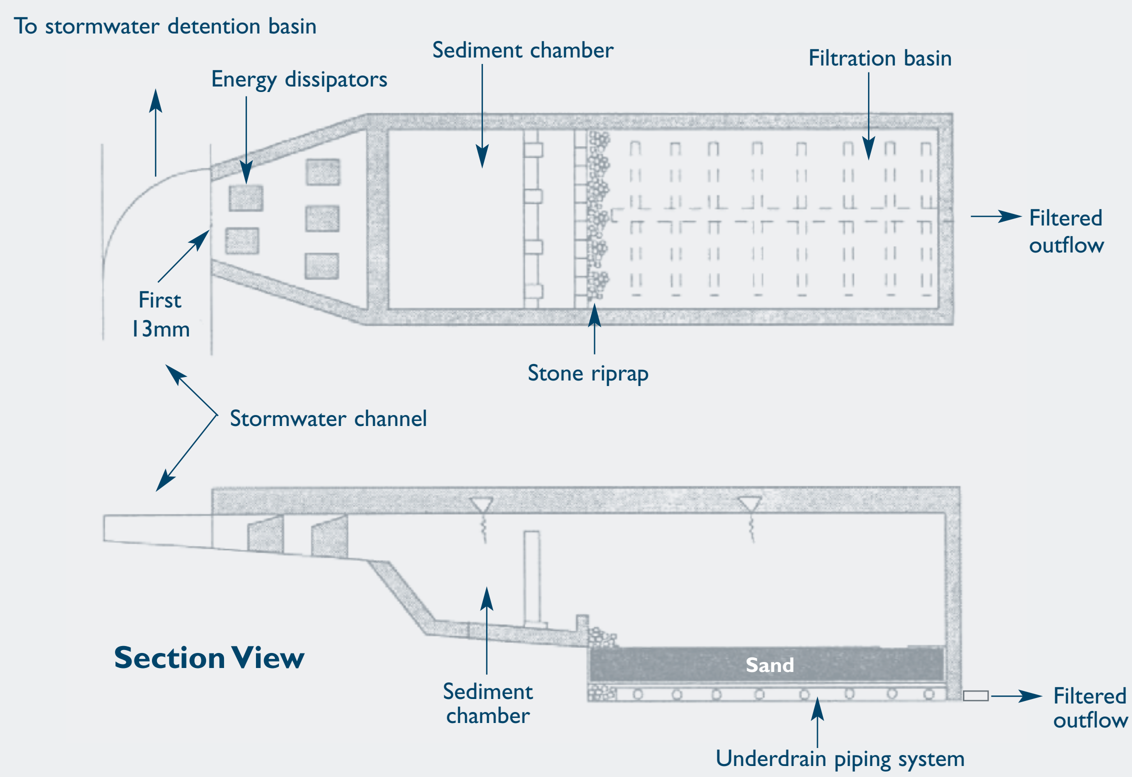
Land Use: Filtering systems are generally applicable to highly impervious sites.

Water Table: At least 3 feet of separation is recommended between the bottom of the filter and the seasonally high groundwater table to maintain adequate drainage, prevent structural damage to the filter, and minimize the potential for interaction with groundwater.

Design Criteria

The design criteria presented in this section are applicable to surface sand filters, bioretention systems, and underground filters. Considerations for specific design variations are also included.

Figure 11-P4-2 Austin Sand Filter



Source: Adapted from FHWA, 1996.

Pretreatment

- *Pretreatment should be provided to store at least 25 percent of the water quality volume and release it to the filter media over a 24-hour period. Storage and pretreatment of the entire water quality volume (also known as "full sedimentation" design) may be required for sites with less than 75 percent imperviousness or sites with unusually high sediment loads.*
- *Pretreatment generally consists of a dry or wet sedimentation chamber or sediment forebay. A length-to-width ratio of between 1.5:1 and 3:1 is recommended for the pretreatment area.*
- *The required surface area of the sedimentation chamber or forebay for full sedimentation design can be determined using the following equation (Camp-Hazen):*

$$A_s = -\frac{Q}{W} \ln (1-E)$$

where: A_s = sedimentation surface area (ft_2)
Q = discharge rate from drainage area (ft^3/s) = $WQV/24hr$*
W = particle settling velocity (0.0004 ft/s recommended for silt)
E = sediment removal efficiency (assume 0.9 or 90%)

*(between 25 and 100 percent of the water quality volume can be used for partial sedimentation design)

Design Volume

- *Surface sand filters should provide at least 75 percent of the water quality volume in the practice (including above the filter, in the filter media voids, and in the pretreatment chamber) and be designed to completely drain in 24 hours or less.*

Filter Bed

- *The filter media for a surface sand filter should consist of medium sand (ASTM C-33 concrete sand). Grain size analysis provided by the supplier is recommended to confirm the sand specification. However, if other media are desired to address specific pollutants, pilot testing is recommended to determine actual hydraulic conductivity.*
- *The required filter bed area should be calculated using the principles of Darcy's Law, which relates the velocity of porous media flow to the hydraulic head and hydraulic conductivity of the filter medium:*

$$A_f = \frac{(WQV)(d)}{[(k)(t)(h+d)]}$$

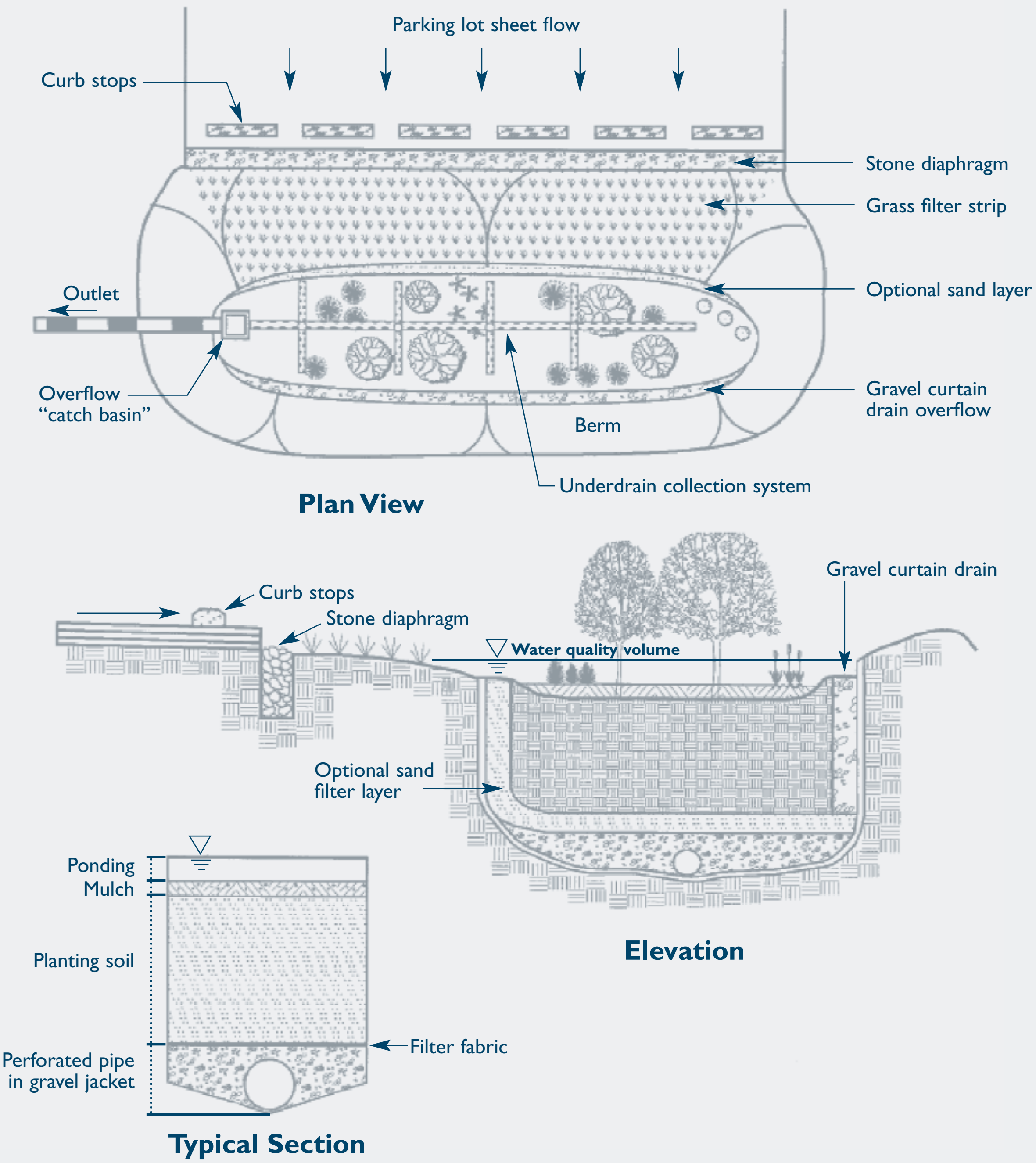
where: A_f = filter bed surface area (ft2)
WQV = water quality volume (ft3)
d = filter bed depth (ft)
k = hydraulic conductivity of filter media (ft/day)
t = time for the water quality volume to drain from the system (24 hours)
h = average height of water above filter bed during water quality design storm

- *A typical hydraulic conductivity value for medium sand is 20 feet per day. Laboratory analysis is recommended to determine the hydraulic conductivity of the actual filter media.*
- *The recommended minimum filter bed depth is 18 inches. Consolidation of the filter media should be taken into account when measuring final bed depth. The surface of the filter bed should be level to ensure equal distribution of flow in the bed.*
- *Mosquito entry points to underground filter systems should be sealed (adult female mosquitoes can use openings as small as 1/16 inch to access water for egg laying).*

Underdrain System

- *The underdrain system should consist of 6-inch diameter or larger PVC perforated pipes reinforced to withstand the weight of the overburden (schedule 40 PVC or greater). A central collector pipe with lateral feeders is a common underdrain piping configuration. The main collector underdrain pipe should have a minimum slope of one percent. The maximum distance between two adjacent lateral feeder pipes is 10 feet.*
- *Perforations in the underdrain piping should be half-inch holes spaced 6 inches apart longitudinally, with rows 120 degrees apart (Metropolitan Council, 2001).*
- *The underdrain piping should be set in 1 to 2-inch diameter stone or gravel washed free of fines and organic material. The stone or gravel layer should provide at least 2 inches of coverage over the tops of the drainage pipes. The stone or gravel layer should be separated from the filter media by a permeable geotextile fabric. Geotextile fabric (and an impermeable liner if*

Figure 11-P4-3 Bioretention



Source: Adapted from Center for Watershed Protection, 2000.

Table 11-P4-1 Liner Specifications

Liner Material	Property	Recommended Specifications
Clay	Minimum Thickness	6 to 12 inches
	Permeability	1×10^{-5} cm/sec[1]
	Particle Size	Minimum 15% passing #200 sieve[1]
Geomembrane	Minimum Thickness	30 mils (0.03 inches)
	Material	Ultraviolet resistant, impermeable poly-liner

Source: [1]NYDEC, 2001; other listed specifications from City of Austin in Washington, 2000 (in Metropolitan Council, 2001).

necessary, see below) should also be placed below the stone or gravel layer.

- *Cleanouts should be provided at both ends of the main collector pipe and extend to the surface of the filter.*

Impermeable Liner

- *An impermeable liner (clay, geomembrane, or concrete) should be used for excavated surface sand filters when infiltration below the filter or pretreatment area could result in groundwater contamination, such as in aquifer protection areas or in areas with the potential for high pollutant loads (e.g. soluble metals and organics).* ***Table 11-P4-1*** *lists recommended specifications for clay and geomembrane liners.*

Conveyance

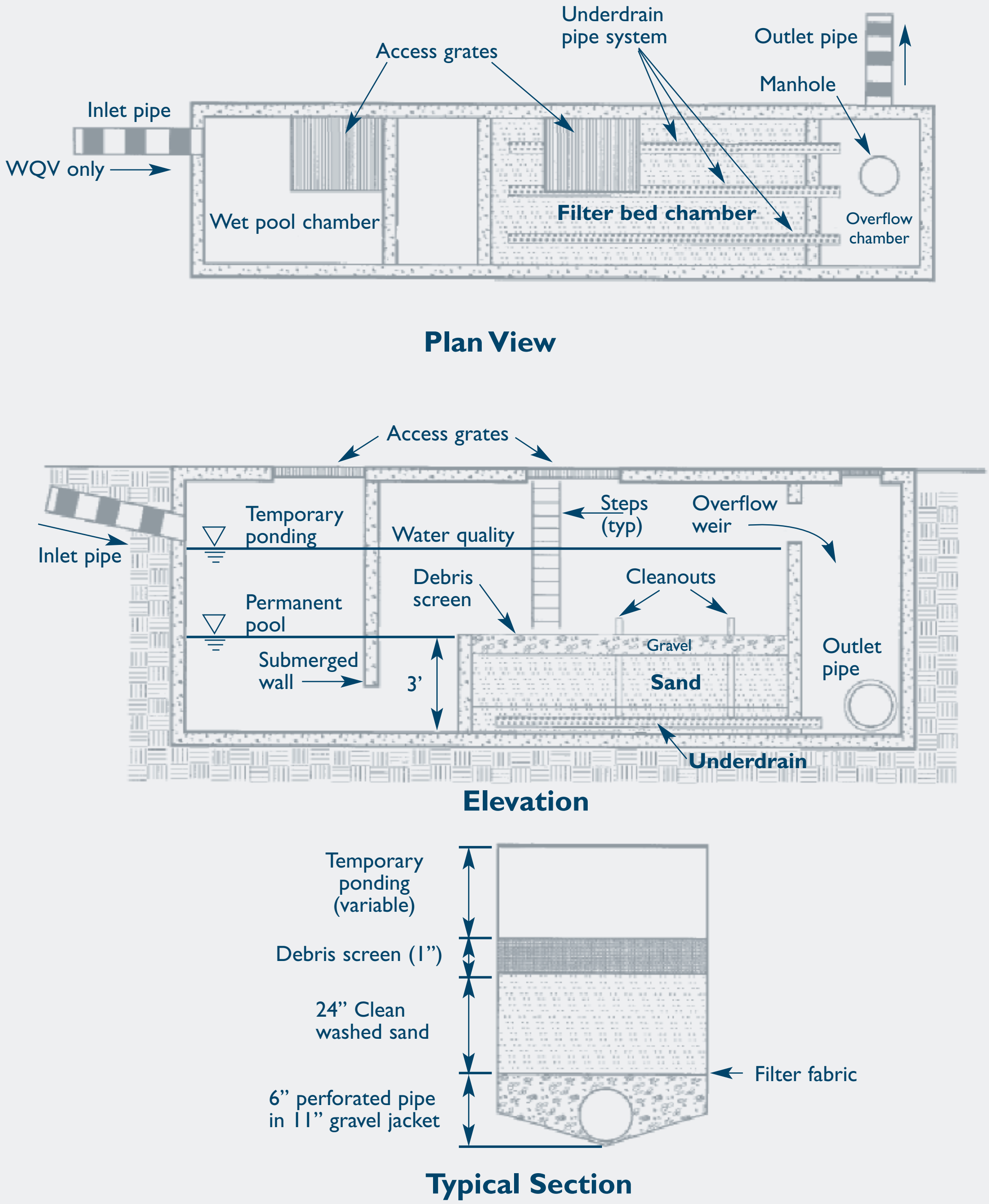
- *A flow diversion structure should be provided to divert the water quality volume to the filtering practice and allow larger flows to bypass the system.*
- *An overflow should be provided within the filtering practice to pass the 10-year design storm to the storm drainage system or stabilized channel.*
- *Inlet structures should be designed to minimize turbulence and spread flow uniformly across the surface of the filter.*
- *Stone riprap or other velocity dissipation methods should be used at the inlet to the filter bed to prevent scour of the filter media.*

Landscaping/Vegetation

- *Planting of surface filters with a grass cover is not recommended since grass clippings can result in reduced permeability or clogging of the filter surface. Grass cover can also conceal the treatment structure or cause it to blend in with surrounding vegetation, thereby potentially resulting in decreased maintenance (i.e., out-of-sight, out-of-mind).*
- *Bioretention facilities generally consist of the following hydric zones:*
  - ***Lowest Zone:*** *The lowest zone supports plant species adapted to standing and fluctuating water levels and corresponds to hydrologic zones 2 and 3 in Table A-1 of Appendix A.*
  - ***Middle Zone:*** *The middle zone supports a slightly drier group of plants, but still tolerates fluctuating water levels. This zone corresponds to hydrologic zones 3 and 4 in* ***Table A-1 of Appendix A****.*
  - ***Outer Zone:*** *The outer or highest zone generally supports plants adapted to drier conditions. This zone corresponds to hydrologic zones 5 and 6 in* ***Table A-1 of Appendix A****.*

(Claytor and Schueler, 1996). Plants should be selected to simulate a terrestrial forested community of native species. The following planting plan design considerations should be followed for bioretention areas:

Figure 11-P4-4 D.C. Underground Sand Filter



Source: Adapted from Center for Watershed Protection, 2000.

- *Use native plant species*
- *Select vegetation based on hydric zones*
- *Plant layout should be random and natural*
- *Establish canopy with an understory of shrubs and herbaceous plants*
- *Do not use woody vegetation near inflow locations*
- *Plant trees along the perimeter of the bioretention area*
- *Do not specify noxious weeds*
- *Wind, sun, exposure, insects, disease, aesthetics, existing utilities, traffic, and safety issues should be considered for plant selection and location.*

(Claytor and Schueler, 1996).

Winter Operation

- *Surface sand filters and perimeter filters can be ineffective during the winter months due to freezing of the filter bed.*
- *Where possible, the filter bed should be below the frost line.*
- *A larger underdrain system (i.e., larger diameter and more frequently spaced underdrain pipes and stone or gravel) may encourage faster draining and reduce the potential for freezing during winter months.*
- *Filters that receive significant road sand should be equipped with a larger pretreatment sediment chamber or forebay.*

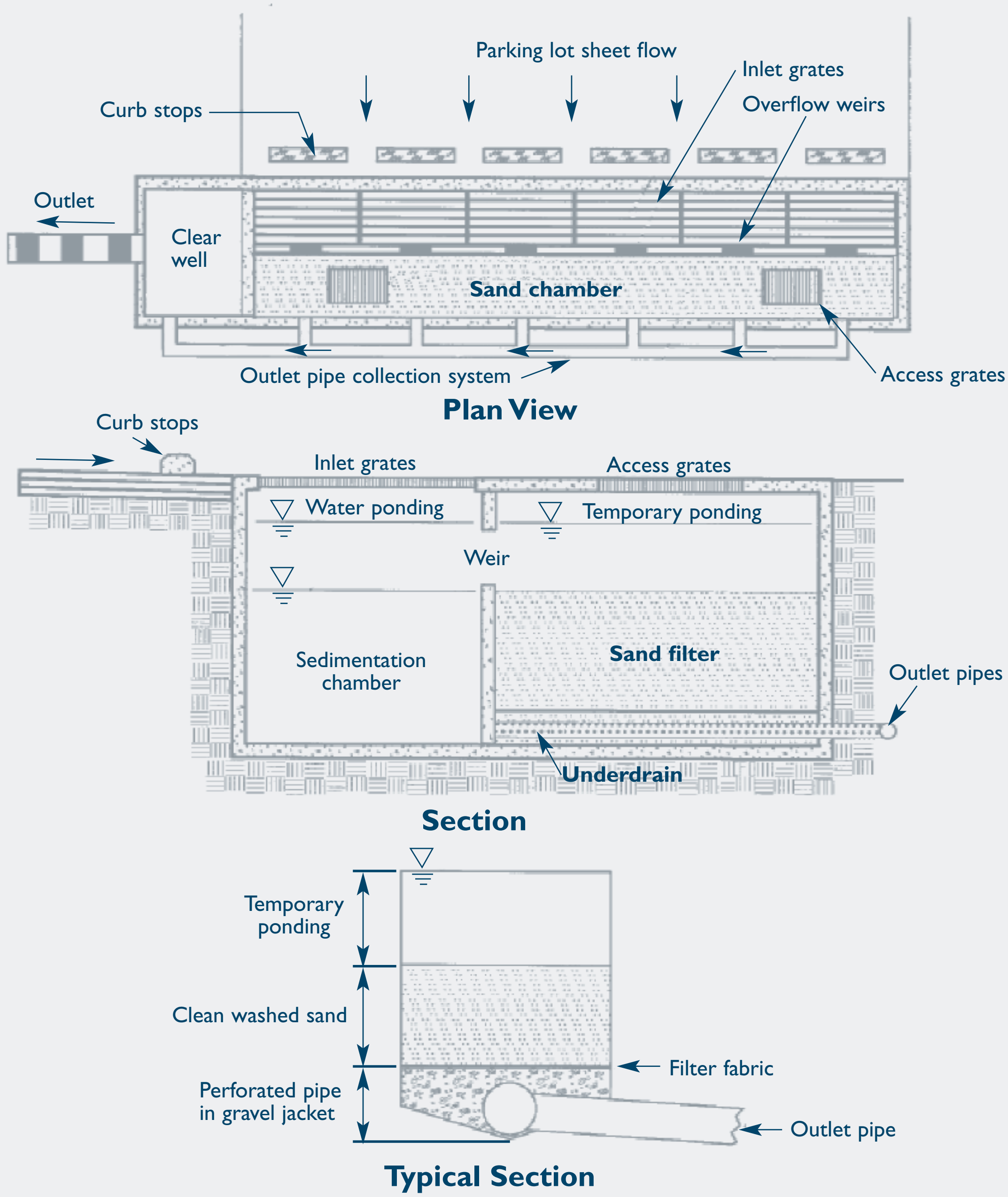
Construction

- *Any stormwater treatment practices that create an embankment, including surface sand filters or similar stormwater filtration systems, are under the jurisdiction of the Dam Safety Section of the Connecticut DEP Inland Water Resources Division (IWRD) and should be constructed, inspected, and maintained in accordance with Connecticut General Statutes §§22a-401 through 22a-411, inclusive, and applicable DEP guidance.*
- *The contributing drainage area should be stabilized to the maximum extent practicable and erosion and sediment controls should be in place during construction.*
- *Filtering systems should not be used as temporary sediment traps for construction erosion and sediment control.*
- *The filter media should be wetted periodically during construction to allow for consolidation of the filter media and proper filter media depth. Sand and other filter media should be carefully placed to avoid formation of voids and short-circuiting.*
- *Over-compaction of the filter media should be avoided to preserve filtration capacity. Mechanical compaction of the filter media should be avoided. Excavation should be performed with backhoes or lightweight equipment rather than loaders.*
- *The underdrain piping should be reinforced to withstand the weight of the overburden.*

Inspection and Maintenance

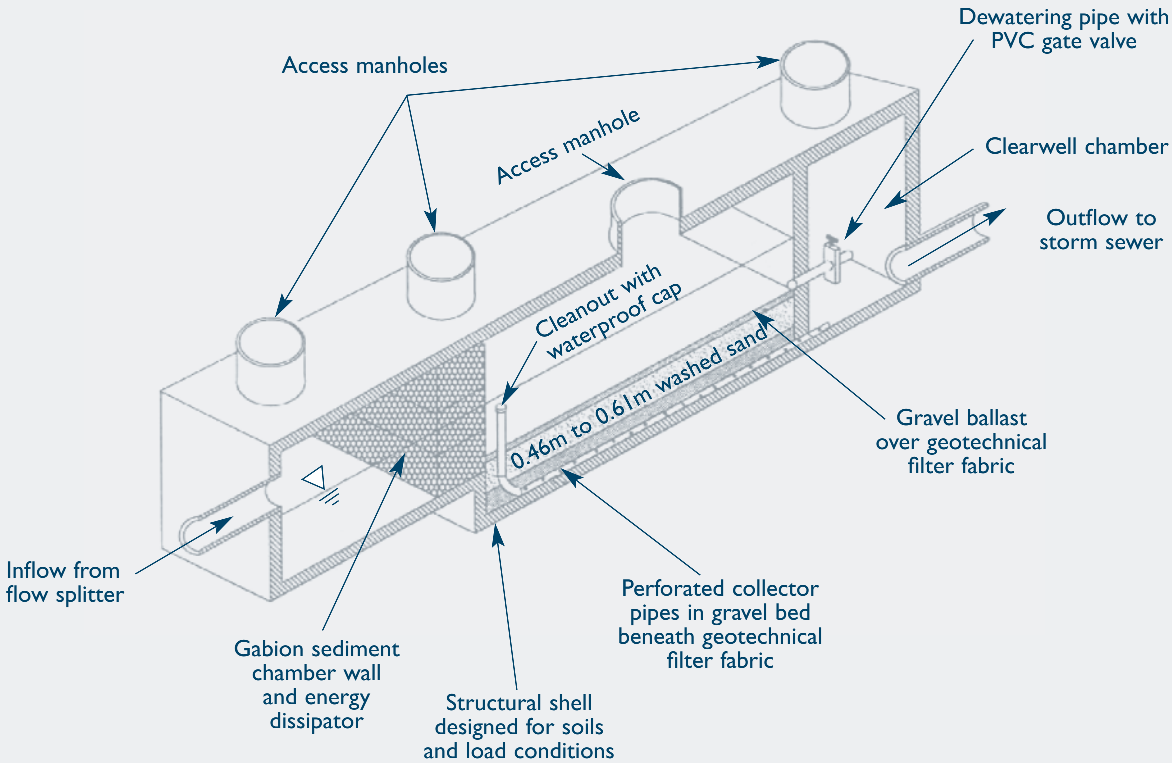
- *Maintenance is critical for the proper operation of filtering systems.*
- *Plans for filtering practices should identify detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance.*
- *Filtering practices should be inspected after every major storm in the first few months following construction. The filter should be inspected at least every 6 months thereafter. Inspections should focus on:*
    - *Checking the filter surface for standing water or other evidence of clogging, such as discolored or accumulated sediments.*
    - *Checking the sedimentation chamber or forebay for sediment accumulation, trash, and debris.*
    - *Checking inlets, outlets, and overflow spillway for blockage, structural integrity, and evidence of erosion.*
- *Sediment should be removed from the sedimentation chamber or forebay when it accumulates to a depth of more than 12 inches or 10 percent of the pretreatment volume. The sedimentation chamber or forebay outlet devices should be cleaned when drawdown times exceed 36 hours.*
- *Sediment should be removed from the filter bed when the accumulation exceeds one inch or when there is evidence that the infiltration*

Figure 11-P4-5 Perimeter (Delaware) Sand Filter



Source: Adapted from Center for Watershed Protection, 2000.

Figure 11-P4-6 Alexandria Underground Sand Filter



Source: Adapted from FHWA, 1996.

capacity of the filter bed has been significantly reduced (i.e., observed water level above the filter exceeds the design level or drawdown time exceeds 36 to 48 hours). As a rule-of-thumb, the top several inches of the filter bed (typically discolored material) should be removed and replaced annually, or more frequently if necessary. The material should be removed with rakes where possible rather than heavy construction equipment to avoid compaction of the filter bed. Heavy equipment could be used if the system is designed with dimensions that allow equipment to be located outside the filter, while a backhoe shovel reaches inside the filter to remove sediment. Removed sediments should be dewatered (if necessary) and disposed of in an acceptable manner.

- *Bioretention areas require seasonal landscaping maintenance, including:*
  - *Watering plants as necessary during first growing season*
  - *Watering as necessary during dry periods*
  - *Re-mulching void areas as necessary*
  - *Treating diseased trees and shrubs as necessary*
  - *Monthly inspection of soil and repairing eroded areas*
  - *Monthly removal of litter and debris*
  - *Adding mulch annually*

(Center for Watershed Protection, 2001).

Cost Considerations

Costs for implementation of stormwater filtering practices are generally higher than other stormwater treatment practices, but vary widely due to many different filter designs. A study by Brown and Schueler (1997) found typical installation costs between $3.00 and $6.00 per cubic foot of stormwater treated. These costs should be adjusted for inflation to reflect current costs. The cost per impervious acre treated varies by region and design variant. While underground filters are generally more expensive to construct than surface filters, they consume no surface space, which makes them relatively cost-effective in ultra-urban areas where land is at a premium (EPA, 1999).

References

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Washington State Department of Ecology (Washington). 2000. *Stormwater Management Manual for Western Washington, Final Draft*. Olympia, Washington.

Water Quality Swales

Source: Nonpoint Education for Municipal Officials (NEMO).

Treatment Practice Type

Primary Treatment Practice	●
Secondary Treatment Practice	

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Significant
Phosphorus	Partial
Nitrogen	Partial
Metals	Partial
Pathogens	Low or Unknown
Floatables	Low or Unknown
Oil and Grease	Low or Unknown
Dissolved Pollutants	Partial
Runoff Volume Reduction	
Runoff Capture	Low or Unknown
Groundwater Recharge*	Partial
Stream Channel Protection	Partial
Peak Flow Control	Low or Unknown

Key: ■ Significant Benefit
■ Partial Benefit
□ Low or Unknown Benefit

*Dry swale design only

Implementation Requirements

Cost ....Low
Maintenance ....Low

Description

Water quality swales are vegetated open channels designed to treat and attenuate the water quality volume and convey excess stormwater runoff. This section includes two types of water quality swales:

- *Dry Swale*
- *Wet Swale*

Water quality swales provide significantly higher pollutant removal than traditional grass drainage channels (see secondary treatment practices), which are designed for conveyance rather than water quality treatment.

Dry swales are designed to temporarily hold the water quality volume of a storm in a pool or series of pools created by permanent check dams at culverts or driveway crossings. The soil bed consists of native soils or highly permeable fill material, underlain by an underdrain system. Pollutants are removed through sedimentation, adsorption, nutrient uptake, and infiltration.

Wet swales also temporarily store and treat the entire water quality volume. However, unlike dry swales, wet swales are constructed directly within existing soils and are not underlain by a soil filter bed or underdrain system. Wet swales store the water quality volume within a series of cells within the channel, which may be formed by berms or check dams and may contain wetland vegetation (Metropolitan Council, 2001). The pollutant removal mechanisms in wet swales are similar to those of stormwater wetlands, which rely on sedimentation, adsorption, and microbial breakdown. Water quality swales can be used in place of curbs, gutters, and storm drain systems on residential and commercial sites to enhance pollutant removal and provide limited groundwater recharge, flood control, and channel protection benefits.

Advantages

- *Provide pretreatment for other stormwater treatment practices by trapping, filtering, and infiltrating pollutants.*
- *Generally lower capital cost than traditional curb and gutter drainage systems.*
- *Reduce the runoff volume through some infiltration and groundwater recharge (particularly for dry swales).*
- *Can be used to divert water around potential pollutant sources.*
- *Provide limited peak runoff attenuation and stream channel protection by reducing runoff velocity and providing temporary storage.*
- *Provide runoff conveyance.*
- *Linear nature makes swales ideal for highway and residential road runoff.*

Limitations

- *Require more maintenance than traditional curb and gutter drainage systems.*
- *Individual dry swales treat a relatively small area.*
- *May be impractical in areas with very flat grades, steep topography, or poorly drained soils (Metropolitan Council, 2001).*
- *Subject to erosion during large storms.*
- *Large area requirements for highly impervious sites.*
- *May not be practical in areas with many driveway culverts or extensive sidewalk systems (MADEP, 1997).*
- *Can produce mosquito-breeding habitat if flat slope, poor drainage, or microtopography created during construction or mowing allows pooling of water for more than 5 days.*

Siting Considerations

Drainage Area: The maximum contributing drainage area for water quality swales should be limited to 5 acres. Conventional grass drainage channels designed primarily for conveyance rather than water quality are appropriate for drainage areas up to 50 acres in size (see Secondary Treatment Practices).

Land Use: Vegetated swales can be readily incorporated into a site drainage plan. Swales are most applicable to low to moderate density land uses such as residential development, small commercial parking lots, and other institutional land uses.

- *Dry swales are primarily designed to receive drainage from small impervious areas, such as small parking lots and rooftops, and rural roads (Claytor and Schueler, 1996).*
- *Wet swales are primarily used for highway runoff, small parking lots, rooftops, and pervious areas (Claytor and Schueler, 1996). Wet swales may not be appropriate in some residential areas because of the potential for stagnant water and nuisance ponding.*

For high density residential, commercial, and industrial land uses, the water quality volume will likely be too large to be accommodated with most swale designs. Swales may be appropriate for pretreatment in conjunction with other practices for these higher density land uses or for stormwater retrofit applications.

Slopes: Site topography should allow for the design of a swale with sufficient slope and cross-sectional area to maintain non-erosive velocities. In areas of steep slopes, swales should run parallel to contours.

Soils and Water Table: Dry swales can be sited on most moderately or well-drained soils. The bottom of the swale should be two to four feet above the seasonal high water table. Wet swales should only be used where the water table is at or near the soil surface or where soil types are poorly drained. When the channel is excavated, the swale bed soils should be saturated most of the time.

Design Criteria

Design considerations for dry and wet swales are presented below and summarized in **Table 11-P5-1.**

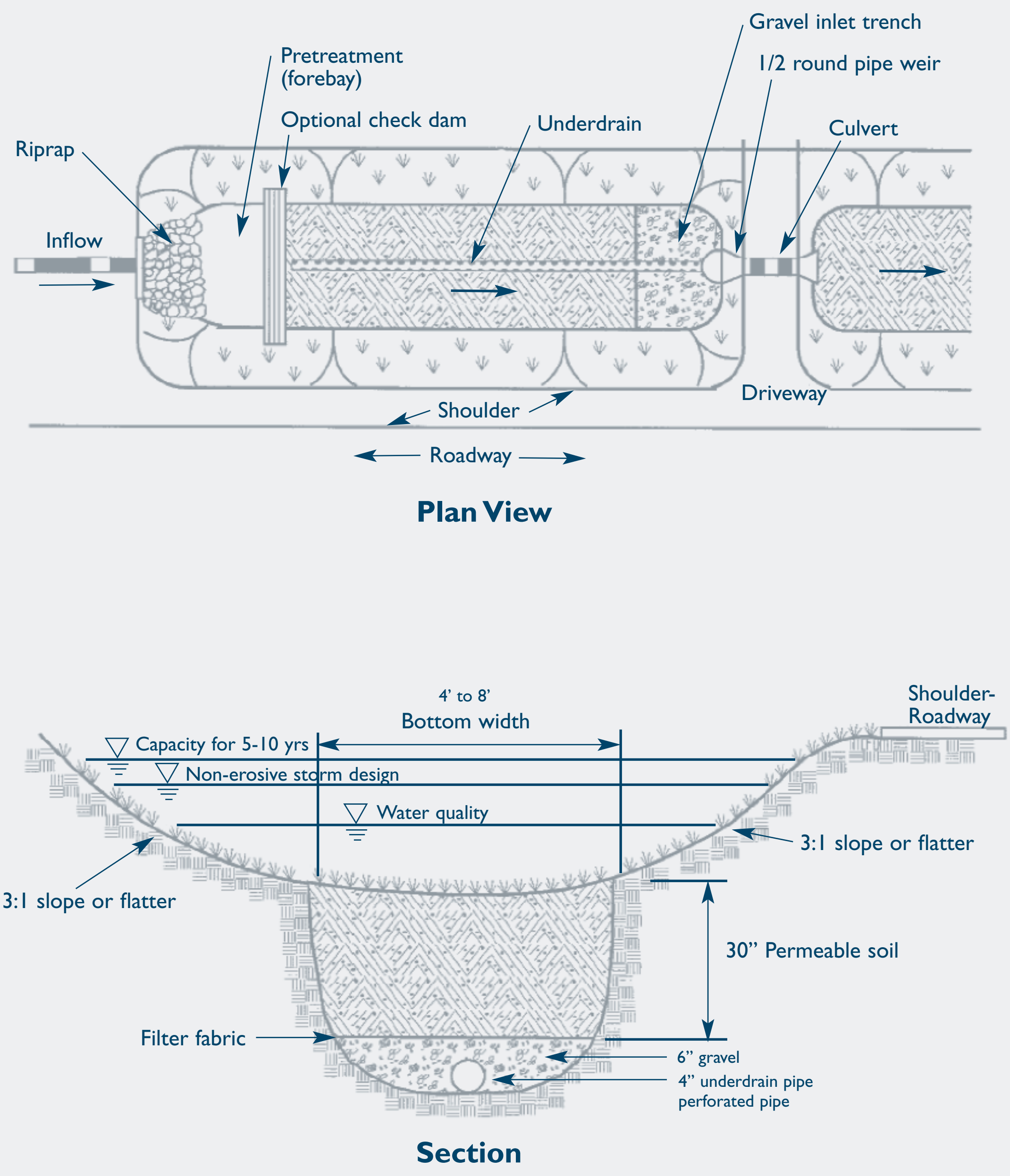
Dry Swale

Figure 11-P5-1 and **Figure 11-P5-2** depict typical schematic designs of dry swales.

Channel Shape and Slope

- *Dry swales should have a trapezoidal or parabolic cross-section with relatively flat side slopes (3:1 horizontal:vertical maximum, 4:1 or flatter recommended for maintenance).*
- *The channel bottom width should be between two and eight feet for construction considera tions, water quality treatment, and to minimize the potential for re-channelization of flow.*

Figure 11-P5-1 Dry Swale – Parabolic Cross Section



Source: Center for Watershed Protection, 2000.

Parameter	Design Criteria
Table 11-P5-1 Design Criteria for Dry and Wet Swales	
Pretreatment Volume	25% of the water quality volume (WQV)
Preferred Shape	Trapezoidal or parabolic
Bottom Width	4 feet minimum recommended for maintenance, 8 feet maximum, widths up to 16 feet are allowable if a dividing berm or structure is used
Side Slopes	3(h):1(v) maximum, 4:1 or flatter recommended for maintenance (where space permits)
Longitudinal Slope	1% to 2% without check dams, up to 5% with check dams
Sizing Criteria	Length, width, depth, and slope needed to provide surface storage for the WQV. ❍ **Dry Swale:** maximum ponding time of 24 hours ❍ **Wet Swale:** retain the WQV for 24 hours; ponding may continue longer (5 days recommended maximum duration to avoid potential for mosquito-breeding)
Underlying Soil Bed	Equal to swale width. ❍ **Dry Swale:** moderately permeable soils (USCS ML, SM, or SC), 30 inches deep with gravel/pipe underdrain system ❍ **Wet Swale:** undisturbed soils, no underdrain system
Depth and Capacity	❍ Surface storage of WQV with a maximum ponding depth of 18 inches for water quality treatment ❍ Safely convey 2-year storm with non-erosive velocity ❍ Adequate capacity for 10-year storm with 6 inches of freeboard

Source: Adapted from Claytor and Schueler, 1996.

- *Check dams may be used to increase in-channel detention, provided that adequate capacity is available to handle peak design flows.*
- *The longitudinal slope of the dry swale should be between one and two percent. Steeper slopes (up to five percent) may be used in conjunction with check dams (vertical drop of 6 to 12 inches). Check dams require additional energy dissipation measures and should be placed no closer than at 50 to 100 foot intervals.*
- *Pretreatment should be provided to accommodate 25 percent of the water quality volume. Pretreatment generally consists of a sediment forebay behind a check dam between the inlet and the main body of the swale. The check dam and area immediately downstream of the check dam should be underlain by a stone base to prevent scour. The check dam may be constructed of timber, concrete, or similar material. Earth and stone check dams are not recommended since they require more maintenance.*
- *Outlet protection is required at the discharge point from a dry swale to prevent scour.*

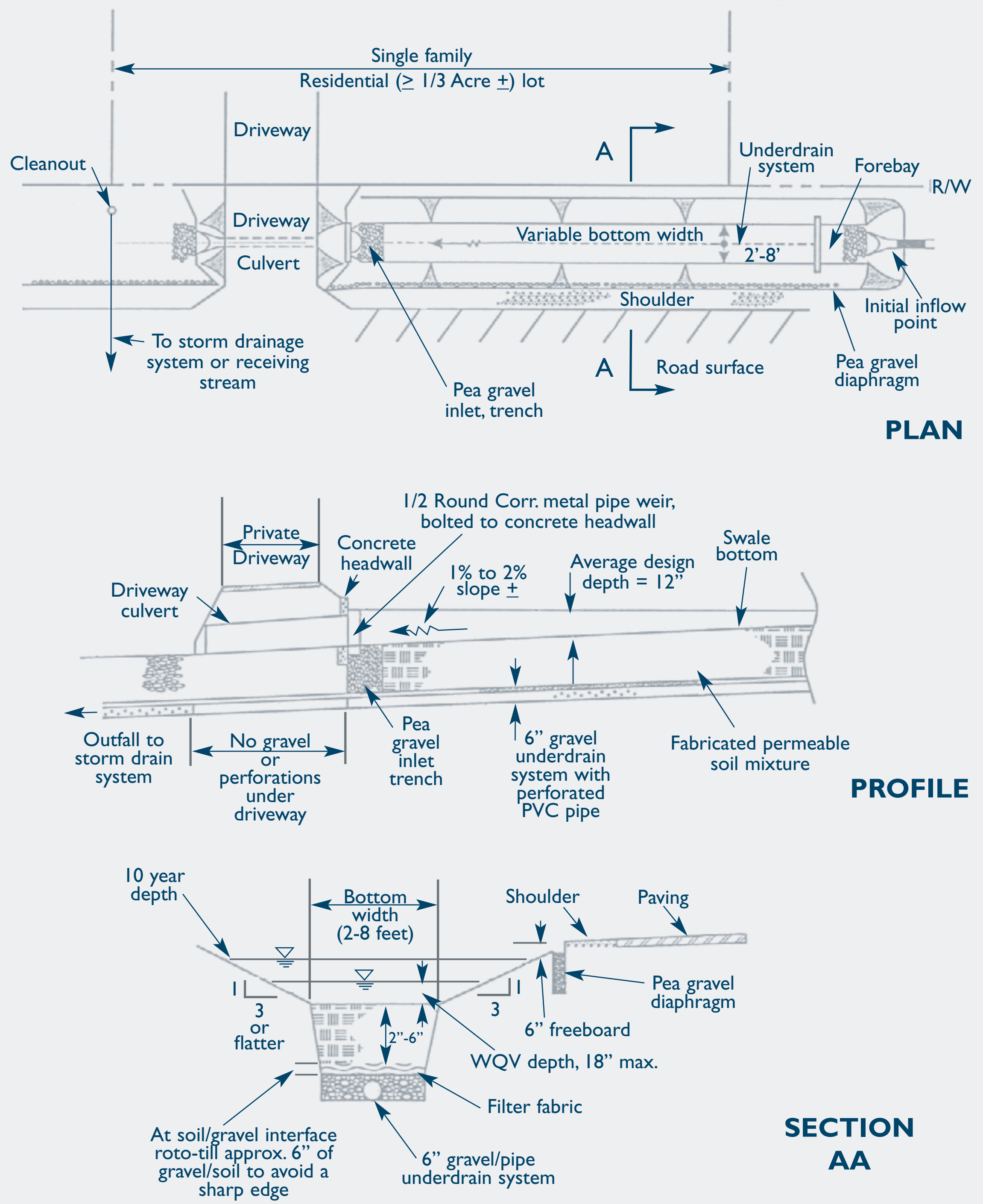
Channel Size

- *Dry swales should be designed to temporarily accommodate the water quality volume through surface ponding (a maximum depth of 18 inches is recommended). Surface ponding should dissipate within 24 hours.*
- *Dry swales should be sized to convey the 10-year storm with a minimum of 6 inches of freeboard, and channel slopes and backs should be designed to prevent erosive channel velocities.*

Underlying Soils

- *Dry swales should have a 30-inch deep soil bed consisting of a sand/loam mixture (approximately 50/50 mix) having an infiltration capacity of at least 1 foot per day.*
- *Where soils do not permit full infiltration, an underdrain system should be installed beneath the soil layer, consisting of a gravel layer surrounding a longitudinally perforated pipe (minimum 6-inch diameter recommended).*

Figure 11-P5-2 Dry Swale – Trapezoidal Cross Section



Source: Claytor and Schueler, 1996.

Vegetation

- *Vegetation should be designed for regular mowing, like a typical lawn, or less frequently (annually or semi-annually).*
- *Native grasses are preferred for enhanced biodiversity, wildlife habitat, and drought tolerance. Grass species should be sod-forming, resistant to frequent inundation, rigid and upright in high flows, and salt tolerant if located along a roadway. Wetland species may be used for the bottom of a wet swale. The maximum velocity should not exceed erosive velocities for the soil type and vegetation condition of the channel (see* ***Connecticut Guidelines for Soil Erosion and Sediment Control*** *for maximum permissible velocities). The following grasses perform well in an open channel environment:*
  - *Red Fescue* (Festuca rubra)
  - *Tall Fescue* (Festuca arundinacea)
  - *Redtop* (Agrostis alba)
  - *Smooth Bromegrass* (Bromus inermis)
  - *Reed Canarygrass* (Phalaris arundinacea L.)

Wet Swale

Figure 11-P5-3 depicts a typical schematic design of a wet swale.

Channel Shape and Slope

- *Wet swales should have a trapezoidal or parabolic cross-section with relatively flat side slopes (3:1 horizontal:vertical maximum, 4:1 or flatter recommended for maintenance).*
- *The channel bottom width should be between four and eight feet.*
- *Check dams may be used to increase in-channel detention, provided that adequate capacity is available to handle peak design flows.*
- *The longitudinal slope of the dry swale should be between one and two percent. Steeper slopes may be used in conjunction with check dams (vertical drop of 6 to 12 inches). Check dams require additional energy dissipation measures and should be placed no closer than at 50 to 100 foot intervals.*
- *Pretreatment should be provided to accommodate 25 percent of the water quality volume. Pretreatment generally consists of a sediment forebay behind a check dam between the inlet and the main body of the swale. The check dam and area immediately downstream of the check dam should be underlain by a stone base to prevent scour. The check dam may be constructed of timber or concrete, and may incorporate v-notch weirs to direct low flow volumes. Earth and stone check dams are not recommended since they require more maintenance.*
- *Outlet protection is required at any discharge point from a wet swale to prevent scour at the outlet.*

Channel Size

- *Wet swales should be designed to temporarily retain the water quality volume for 24 hours, but ponding may continue for longer periods depending on the depth and elevation to the water table (5 days recommended maximum duration to reduce the potential for mosquito breeding). A maximum ponding depth of 18 inches (at the end point of the channel) is recommended for storage of the water quality volume.*
- *Wet swales should be sized to convey the 10-year storm with a minimum of 6 inches of freeboard, and channel slopes and backs should be designed to prevent erosive velocities.*

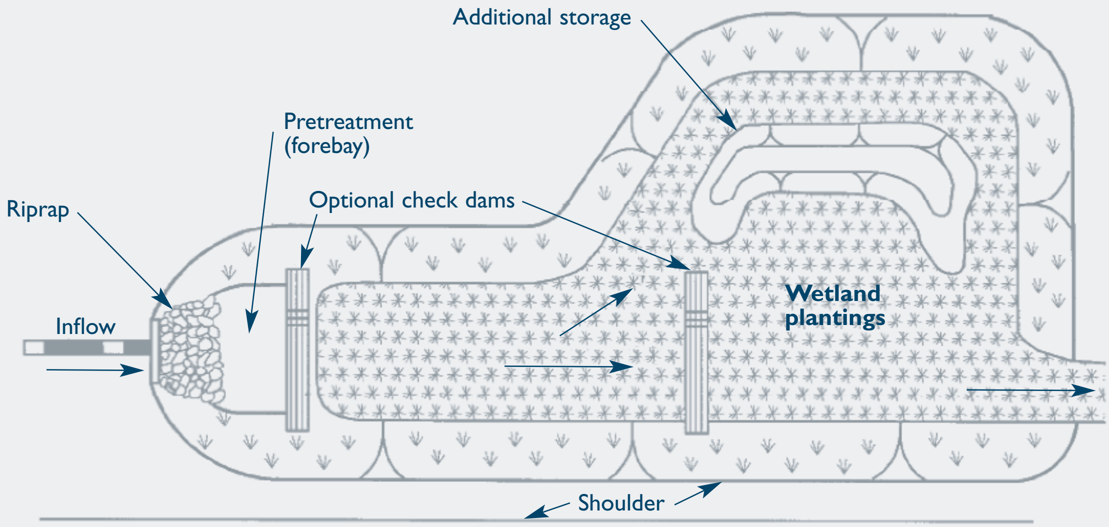
Underlying Soils

- *The soil bed below wet swales should consist of undisturbed soils. This area may be periodically inundated and remain wet for extended periods.*
- *Wet swales should not be constructed in gravelly and coarse sandy soils that cannot easily support dense vegetation.*

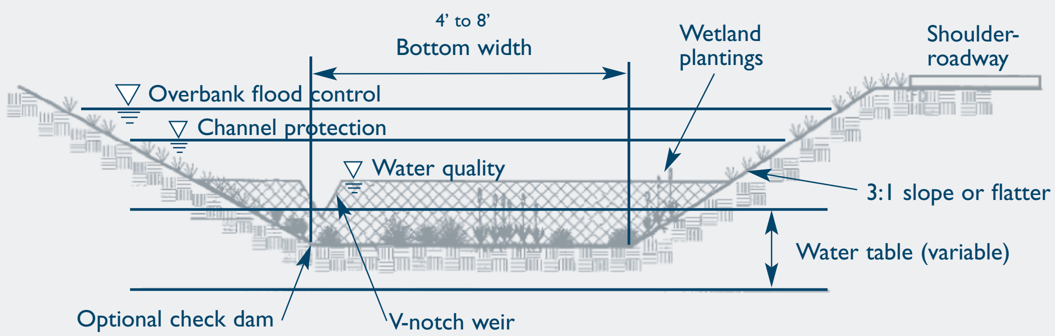
Vegetation

- *The permanent channel vegetation should be suitable for the site and soil conditions.*
- *Native grasses are preferred for enhanced biodiversity and wildlife habitat. Grass species should be resistant to sustained inundation and/or a high water table and salt tolerant if located along a roadway. Wetland species are appropriate for the bottom of a wet swale. The maximum velocity should not exceed erosive velocities for the soil type and vegetation condition of the channel (see* ***Connecticut Guidelines for Soil Erosion and Sediment Control*** *for maximum permissible velocities). The following grasses perform well in an open channel environment:*
  - *Red Fescue* (Festuca rubra)
  - *Tall Fescue* (Festuca arundinacea)
  - *Redtop* (Agrostis alba)

Figure 11-P5-3 Wet Swale



Plan View



Section

Source: Adapted from Center for Watershed Protection, 2000.

- *Smooth Bromegrass* (Bromus inermis)
- *Reed Canarygrass* (Phalaris arundinacea L.)

Construction

- *Avoid soil compaction and the creation of micro-topography that could result in pooling of water for more than 5 days.*
- *Accurate grading is critical to the proper functioning of the swale and will affect the treatment performance.*
- *Temporary erosion and sediment controls should be used during construction.*
- *Appropriate soil stabilization methods should be used before permanent vegetation is established. Seeding, sodding, and other temporary soil stabilization controls should be implemented in accordance with the* ***Connecticut Guidelines for Soil Erosion and Sediment Control.***

Inspection and Maintenance

- *Plans for water quality swales should identify detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance.*
- *Inspect swales several times during the first few months to ensure that grass cover is established. Inspect swales semi-annually for the remainder of the first year and after major storm events. Annual inspections are sufficient after the first year.*
- *The initial sediment forebay should be inspected annually for clogging and sediment buildup. Sediment buildup should be removed when approximately 25 percent of the water quality volume or channel capacity has been exceeded. Excessive trash and debris should be removed and disposed of in an appropriate location.*
- *The vegetation along the swale bottom and side slopes should be inspected for erosion and repaired (seeded or sodded), as necessary.*
- *Grass should be mowed on a regular basis, but at least once per year. Dry swales should be mowed as required to maintain grass heights of 4 to 6 inches during the growing season. Wet swales, which typically incorporate wetland vegetation, require less frequent mowing. To avoid the creation of ruts and compaction, which can reduce infiltration and lead to poor drainage, mowing should not be performed when the ground is soft..*

Cost Considerations

Limited data exist on the cost to implement water quality swales, although they are relatively inexpensive to construct compared to other stormwater treatment practices. The cost to design and construct most water quality swales can be estimated as $0.50 per square foot of swale surface area, based on 1997 prices (EPA, 1999). These costs should be adjusted for inflation to reflect current costs.

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Dry Detention Ponds

Source: Nonpoint Education for Municipal Officials (NEMO).

Treatment Practice Type

Primary Treatment Practice
Secondary Treatment Practice ●

Stormwater Management Benefits

Pollutant Reduction

- Sediment ▨
- Phosphorus □
- Nitrogen □
- Metals □
- Pathogens □
- Floatables* ▨
- Oil and Grease* ▨
- Dissolved Pollutants □

Runoff Volume Reduction

- Runoff Capture □
- Groundwater Recharge ▨

Stream Channel Protection ■

Peak Flow Control ■

Key: ■ Significant Benefit
▨ Partial Benefit
□ Low or Unknown Benefit

*Only if a skimmer is used

Suitable Applications

- Pretreatment □
- Treatment Train ■
- Ultra-Urban □
- Stormwater Retrofits □
- Other □

Description

Dry detention ponds, also known as "dry ponds" or "detention basins", are stormwater basins designed to capture, temporarily hold, and gradually release a volume of stormwater runoff to attenuate and delay stormwater runoff peaks. Dry detention ponds provide water quantity control (peak flow control and stream channel protection) as opposed to water quality control. The outlet structure of a dry detention pond is located at the bottom of the pond and sized to limit the maximum flow rate. Dry ponds are designed to completely empty out, typically in less than 24 hours, resulting in limited settling of particulate matter and the potential for re-suspension of sediment by subsequent runoff events. Conventional dry detention ponds differ from extended detention ponds, which provide a minimum 24-hour detention time and enhanced pollutant removal (*see* Stormwater Ponds section of this chapter). Dry detention ponds are not suitable as infiltration or groundwater recharge measures, and therefore do not reduce runoff volumes. **Figure 11-S1-1** shows a schematic of a typical dry detention pond.

Reasons for Limited Use

- *Not intended for water quality treatment. Most dry detention ponds have detention times of less than 24 hours and lack a permanent pool, providing insufficient settling of particles, and minimal stormwater treatment.*
- *Susceptible to re-suspension of settled material by subsequent storms.*
- *Generally require a drainage area of 10 acres or greater to avoid an excessively small outlet structure susceptible to clogging.*

Suitable Applications

- *Primarily for water quantity control to attenuate peak flows, limit downstream flooding, and provide some degree of channel protection.*

- *Low-density residential, industrial, and commercial developments with adequate space and low visibility.*
- *As part of a stormwater treatment train, particularly in combination with other primary or secondary treatment practices that provide pollutant reduction, runoff volume reduction, or groundwater recharge. The size of dry ponds can be reduced substantially by placing them at the end of the treatment train to take advantage of reduced runoff volume resulting from upstream practices that employ infiltration.*
- *Less frequently used portions of larger or regional dry detention basins can offer recreational, aesthetic, or open space opportunities (e.g., athletic fields, jogging and walking trails, picnic areas).*

Design Considerations

The design of detention ponds is dictated by local stormwater quantity control requirements. Local ordinances typically require that post-development peak flows be controlled to pre-development levels for storms ranging from 2-year through 100-year return periods. Control of more frequent events may also be required. The reader should consult the local authority for specific quantity control requirements, as well as the following references for guidance on the design and implementation of conventional dry detention ponds for stormwater quantity control:

- Connecticut Department of Transportation (ConnDOT), *Connecticut Department of Transportation Drainage Manual,* October 2000.
- Water Environment Federation (WEF) and American Society of Civil Engineers (ASCE), *Design and Construction of Urban Stormwater Management Systems (Urban Runoff Quality Management (WEF Manual of Practice FD-20 and ASCE Manual and Report on Engineering Practice No. 77), 1992.*

Whenever possible, detention ponds should be designed as extended detention ponds or wet ponds, or used in conjunction with other stormwater treatment practices to provide water quality benefits. Extended detention ponds, which are considered primary stormwater treatment practices (see the Stormwater Ponds section of this chapter), are modified dry detention ponds that incorporate a number of enhancements for improved water quality function. Older, existing dry ponds are also good candidates for stormwater retrofits by incorporating these recommended enhancements (see Chapter Ten), which are summarized below.

Sediment Forebay: A sediment forebay is an additional storage area near the inlet of the pond that facilitates maintenance and improves pollutant removal by capturing large particles. Sediment forebays can be created by berms or baffles constructed of stone, riprap, gabions or similar materials. The forebay should include a deep permanent pool to minimize the potential for scour and re-suspension (Metropolitan Council, 2001).

Extended Detention Storage: Extended detention requires sufficient storage capacity to hold stormwater for at least 24 hours to allow solids to settle out. The additional storage volume is usually provided in the lower stages of the pond for treatment of smaller storms associated with the water quality volume, while the upper stages provide storage capacity for large, infrequent storms. To reduce the potential for mosquito breeding, detention ponds should not be designed to hold water for longer than 5 days.

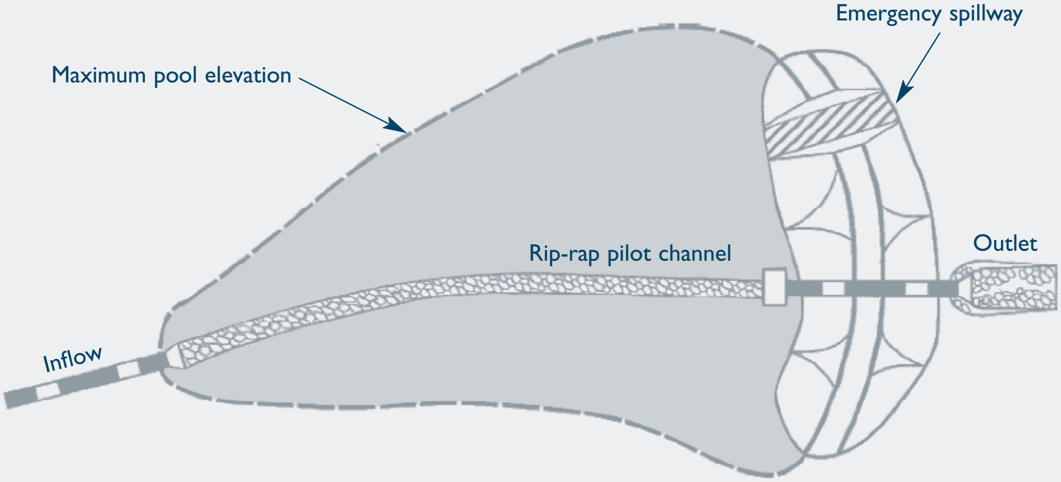
Any stormwater treatment practices that create an embankment, including stormwater detention ponds, are under the jurisdiction of the Dam Safety Section of the Connecticut DEP Inland Water Resources Division (IWRD) and should be constructed, inspected, and maintained in accordance with Connecticut General Statutes §§22a-401 through 22a-411, inclusive, and applicable DEP guidance.

Outlet Wet Pool: A relatively shallow, permanent pool of water at the pond outlet can provide additional pollutant removal by settling finer sediment and reducing re-suspension. The wet pool or micropool can also be planted with wetland species to enhance pollutant removal.

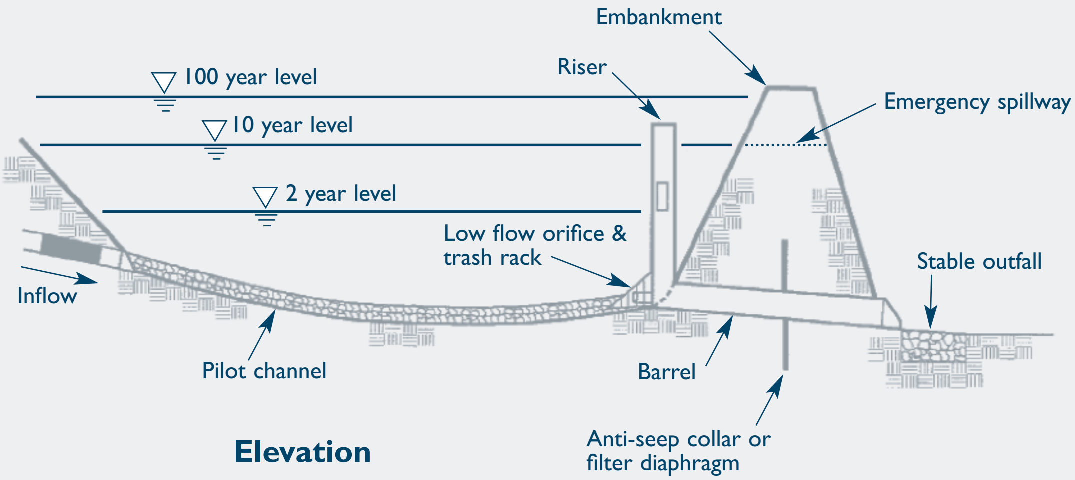
Pond Configuration: The inlet and outlet of the pond should be positioned to minimize short-circuiting. Baffles and internal grading can be used to lengthen the flow path within the pond. A minimum length-to-width ratio of 2:1 is recommended, and irregularly shaped ponds are desirable due to their more natural and less engineered appearance.

Low Flow Channels: Low flow channels prevent erosion as runoff first enters a dry pond during the initial period of a storm event, and after a storm, route the final portion to the pond outlet.

Figure 11-S1-1 Dry Detention Pond



Plan View



Elevation

Source: Adapted from Center for Watershed Protection, 2000.

References

Center for Watershed Protection (CWP). 2000. *The Vermont Stormwater Management Handbook Technical Support Document – Public Review Draft*. Prepared For Vermont Agency of Natural Resources.

Connecticut Department of Transportation (DOT). 2000. *Connecticut Department of Transportation Drainage Manual*.

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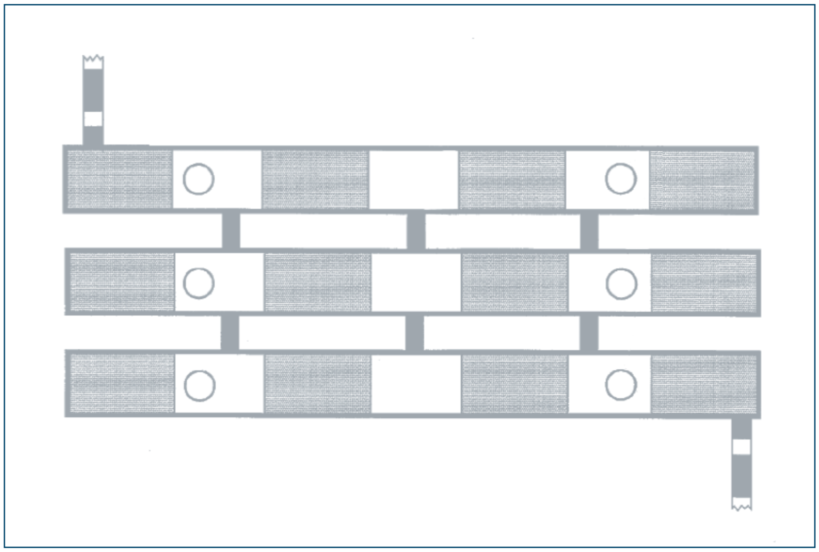
Underground Detention Facilities



Source: Adapted from Center for Watershed Protection, 2000.

Treatment Practice Type

Primary Treatment Practice	
Secondary Treatment Practice	●

Stormwater Management Benefits

Pollutant Reduction	
Sediment	□
Phosphorus	□
Nitrogen	□
Metals	□
Pathogens	□
Floatables	□
Oil and Grease	□
Dissolved Pollutants	□
Runoff Volume Reduction	
Runoff Capture	□
Groundwater Recharge	□
Stream Channel Protection	■
Peak Flow Control	■

Key: ■ Significant Benefit
▪ Partial Benefit
□ Low or Unknown Benefit

Suitable Applications

Pretreatment	□
Treatment Train	■
Ultra-Urban	■
Stormwater Retrofits	■
Other	□

Description

Underground detention facilities such as vaults, pipes, tanks, and other subsurface structures are designed to temporarily store stormwater runoff for water quantity control. Like aboveground detention ponds, underground detention facilities are designed to drain completely between runoff events, thereby providing storage capacity for subsequent events. Underground detention facilities are intended to control peak flows, limit downstream flooding, and provide some channel protection. However, they provide little, if any, pollutant removal (i.e., settling of coarse sediment) and are susceptible to re-suspension of sediment during subsequent storms. **Figure 11-S2-1** depicts a typical underground detention pipe system. Other modular lattice or pipe systems such as those described in the "Underground Infiltration Facilities" section of this chapter can be used as detention facilities rather than for exfiltration.

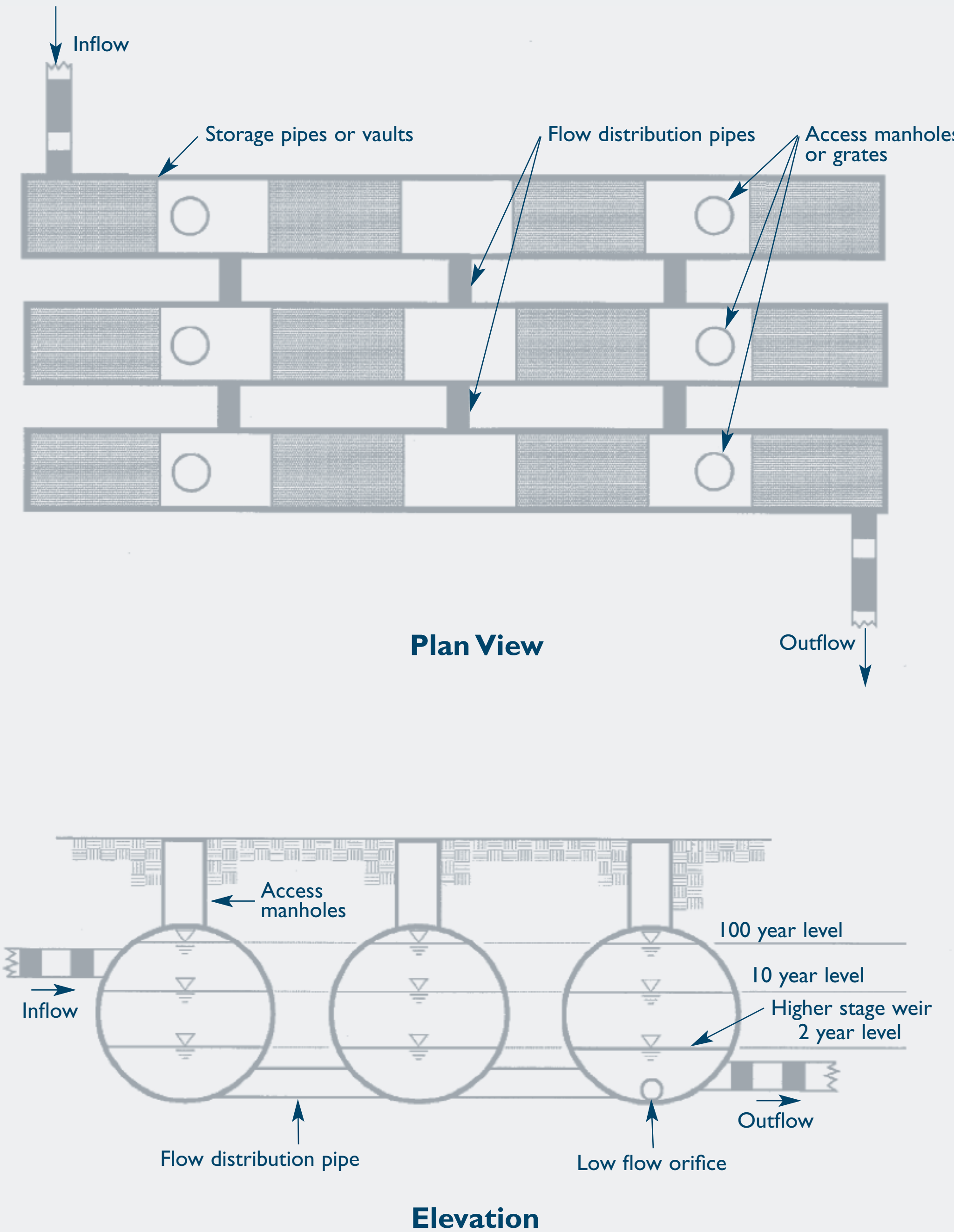
Reasons for Limited Use

- *Not intended for water quality treatment. Typically provide less than 24 hours of detention time.*
- *Susceptible to re-suspension of settled material by subsequent storms.*
- *Do not reduce runoff volume or promote groundwater recharge.*

Suitable Applications

- *Primarily for water quantity control to attenuate peak flows, limit downstream flooding, and provide some degree of channel protection.*
- *Suitable for stormwater quantity control at space-limited sites where traditional aboveground detention facilities are impractical due to excessive space requirements. These systems can be installed under parking lots and other developed areas, provided that the system can be accessed for maintenance purposes.*

Figure 11-S2-1 Underground Detention Pipe System



Source: Adapted from Center for Watershed Protection, 2000.

- *Useful in stormwater retrofit applications to provide additional temporary storage volume and attenuate peak flows.*
- *As part of a stormwater treatment train, particularly in combination with other primary or secondary treatment practices that provide pollutant reduction, runoff volume reduction, or groundwater recharge.*

Design Considerations

Siting: Underground detention systems are generally applicable to small development sites and should be installed in locations that are easily accessible for routine and non-routine maintenance. These systems should not be located in areas or below structures that cannot be excavated in the event that the system needs to be replaced. Access manholes should be located at upstream, downstream, and intermediate locations, as appropriate

Pretreatment: Appropriate pretreatment (e.g., oil/particle separator, hydrodynamic device, catch basin inserts, or other secondary or primary treatment practices) should be provided to minimize the quantity of sediment that reaches the detention system.

Inlets, Outlets, and Overflows: Underground systems are typically designed as on-line systems that capture frequent runoff events from paved areas. Outlets are sized to restrict maximum flow rates in accordance with local peak flow control requirements, such as controlling post-development peak flows to pre-development levels for storms ranging from 2-year through 100-year return periods. Emergency surface overflows should be designed to convey the 100-year runoff in case the outlet becomes clogged. Potential mosquito entry points should be sealed (adult female mosquitoes can use openings as small as 1/16 inch to access water for egg laying).

References

Center for Watershed Protection (CWP). 2000. *The Vermont Stormwater Management Handbook Technical Support Document – Public Review Draft*. Prepared For Vermont Agency of Natural Resources.

United States Environmental Protection Agency (EPA). 1999. *Storm Water Technology Fact Sheet: Infiltration Drainfields*. EPA 832-F-99-018. Office of Water. Washington, D.C.

United States Environmental Protection Agency (EPA). 2002. *National Menu of Best Management Practices for Stormwater Phase II*. URL: http://www.epa.gov/npdes/menuofbmps/menu.htm,

Deep Sump Catch Basins

Source: Nonpoint Education for Municipal Officials (NEMO).

Treatment Practice Type

Primary Treatment Practice
Secondary Treatment Practice ●

Stormwater Management Benefits

Pollutant Reduction	
Sediment	▣
Phosphorus	□
Nitrogen	□
Metals	□
Pathogens	□
Floatables	▣
Oil and Grease	▣
Dissolved Pollutants	□
Runoff Volume Reduction	
Runoff Capture	□
Groundwater Recharge	□
Stream Channel Protection	□
Peak Flow Control	□

Key: ■ Significant Benefit
▣ Partial Benefit
□ Low or Unknown Benefit

Suitable Applications

Pretreatment	■
Treatment Train	■
Ultra-Urban	■
Stormwater Retrofits	■
Other	□

Description

Deep sump catch basins, also known as oil and grease catch basins, are storm drain inlets that typically include a grate or curb inlet and a sump to capture trash, debris, and some sediment and oil and grease. Stormwater runoff enters the catch basin via an inlet pipe located at the top of the basin. The basin outlet pipe is located below the inlet and can be equipped with a hood (i.e., an inverted pipe). Floatables such as trash and oil and grease are trapped on the permanent pool of water, while coarse sediment settles to the bottom of the basin sump. **Figure 11-S3-1** shows a schematic of a typical deep sump catch basin.

Catch basins are commonly used in drainage systems and can be used as pretreatment for other stormwater treatment practices. However, most catch basins are not ideally designed for sediment and pollutant removal. The performance of deep sump catch basins at removing sediment and associated pollutants depends on several factors including the size of the sump, the presence of a hooded outlet, and maintenance frequency.

Reasons for Limited Use

Catch basins have several major limitations, including:

- *Even ideally designed catch basins (those with deep sumps, hooded outlets, and adequate sump capacity) are far less effective at removing pollutants than primary stormwater management practices such as stormwater ponds, wetlands, filters, and infiltration practices.*
- *Can become a source of pollutants unless maintained frequently.*
- *Sediments can be re-suspended and floatables may be passed downstream during large storms.*
- *Cannot effectively remove soluble pollutants or fine particles.*
- *May become mosquito breeding habitat between rainfall events.*

(EPA, 2002).

Suitable Applications

- *For limited removal of trash, debris, oil and grease, and sediment from stormwater runoff from relatively small impervious areas (parking lots, gas stations, and other commercial development).*
- *To provide pretreatment for other stormwater treatment practices.*
- *For retrofit of existing stormwater drainage systems to provide floatables and limited sediment control. See Chapter Ten for examples of catch basin stormwater retrofits.*

Design Considerations

Drainage Area: The contributing drainage area to any deep sump catch basin generally should not exceed 1/4 acre of impervious cover.

Design: Catch basin performance is related to the volume of the sump below the outlet. A recommended catch basin sizing criterion relates the catch basin sump depth to the diameter of the outlet pipe (D), as follows:

- *The sump depth (distance from the bottom of the outlet pipe to the bottom of the basin) should be at least 4D and increased if cleaning is infrequent or if the contributing drainage area has high sediment loads.*
- *The diameter of the catch basin should be at least 4 feet.*
- *The bottom of the outlet pipe should be at least 4 feet from the bottom of the catch basin inlet grate.*

(Lager et al., 1997). Where high sediment loads are anticipated, the catch basin can be sized to accommodate the volume of sediment that enters the system, with a factor of safety (Pitt et al., 2000).

Where feasible, deep sump catch basins should be designed as off-line systems (i.e., collectors or preceded by a flow diversion structure) to minimize re-suspension of sediment during large storms. The basic design should also incorporate a hooded outlet consisting of an inverted elbow pipe to prevent floatable materials and trash from entering the storm drainage system. Hooded outlets may be impractical for outlet pipes larger than 24 inches in diameter. Catch basin hoods that reduce or eliminate siphoning should be used. Catch basins should be watertight to maintain a permanent pool of water and provide higher floatable capture efficiency. Catch basin inserts, which are described elsewhere in this chapter, can be used to filter runoff entering the catch basin, although their effectiveness is unproven and they require frequent sediment removal.

Maintenance: Typical maintenance of catch basins includes trash removal from the grate (and screen or other debris-capturing device if one is used) and removal of sediment using a vacuum truck. Studies have shown that catch basins can capture sediments up to approximately 50 percent of the sump volume. Above this volume, catch basins reach steady state due to re-suspension of sediment (Pitt, 1984). Frequent cleanout maintains available sump volume for treatment purposes.

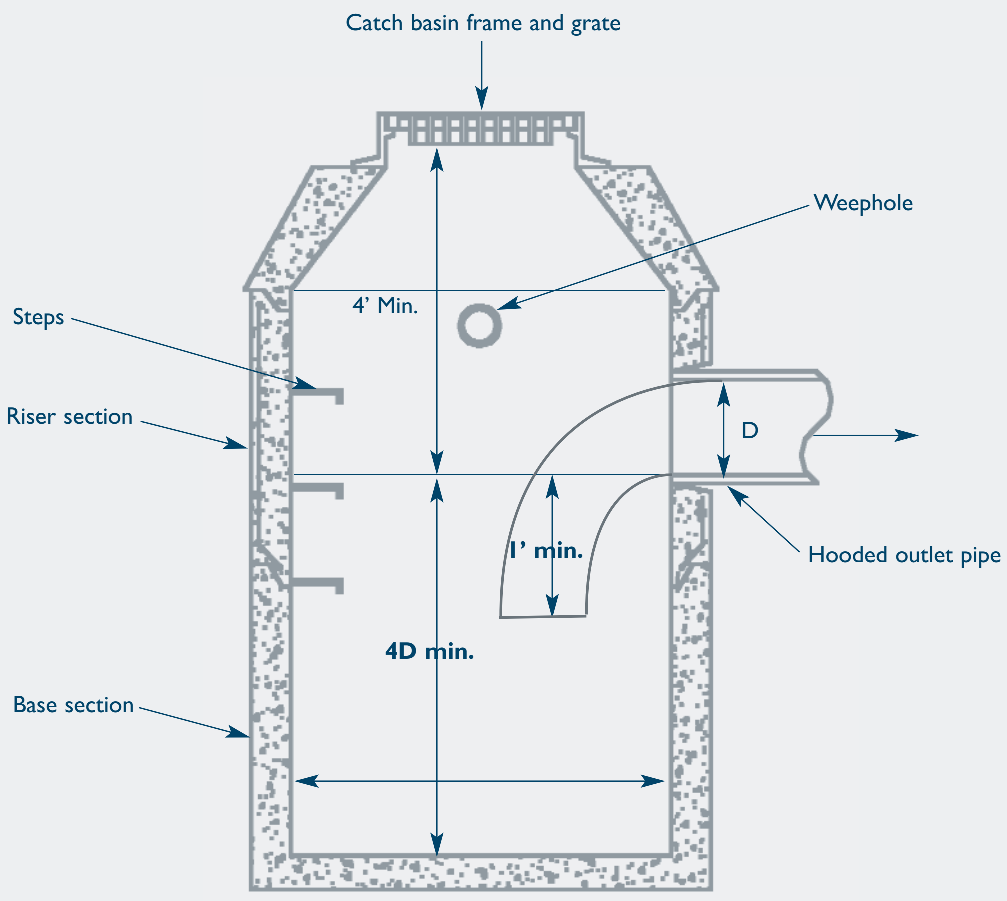
Catch basins should be cleaned at least annually, after the snow and ice removal season is over and as soon as possible before spring rainfall events. In general, a catch basin should be cleaned if the depth of deposits is greater than or equal to one-half the depth from the bottom of the basin to the invert of the lowest pipe in the basin (EPA, 1999). If a catch basin significantly exceeds this one-half depth standard during the annual inspection, then it should be cleaned more frequently.

In addition, areas with higher pollutant loadings or discharging to sensitive water bodies should also be cleaned more frequently (WEF and ASCE, 1998). More frequent cleaning of drainage systems may also be needed in areas with relatively flat grades or low flows since they may rarely achieve sufficiently high flows for self-flushing (Fergusen et al., 1997).

Plans for catch basins should identify detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance.

Sediment Disposal: Polluted water or sediment removed from catch basins should be properly handled and disposed in accordance with local, state, and federal regulations. Before disposal, an appropriate chemical analysis of the material should be performed to determine proper methods for storage and disposal (EPA, 1999).

Figure 11-S3-1 Typical Deep Sump Catch Basin



Source: Adapted from Urban Stormwater Management and Technology: Update and Users' Guide, 1977.

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Ferguson, T., Gignac, R., Stoffan, M., Ibrahim, A., and J. Aldrich. 1997. *Rouge River national Wet Weather Demonstration Project: Cost Estimating Guidelines, Best Management Practices and Engineered Controls*. Wayne County, Michigan.

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Pitt, R. and P. Bissonnette. 1984. *Bellevue Urban Runoff Program Summary Report*. U.S. Environmental Protection Agency. Water Planning Division. Washington, D.C..

Pitt, R.M., Nix, S., Durrans, S.R., Burian, S., Voorhees, J., and J. Martinson. 2000. *Guidance Manual for Integrated Wet Weather Flow (WWF) Collection and Treatment Systems for Newly Urbanized Areas (New WWF Systems)*. U.S. Environmental Protection Agency. Office of Research and Development. Cincinnati, Ohio.

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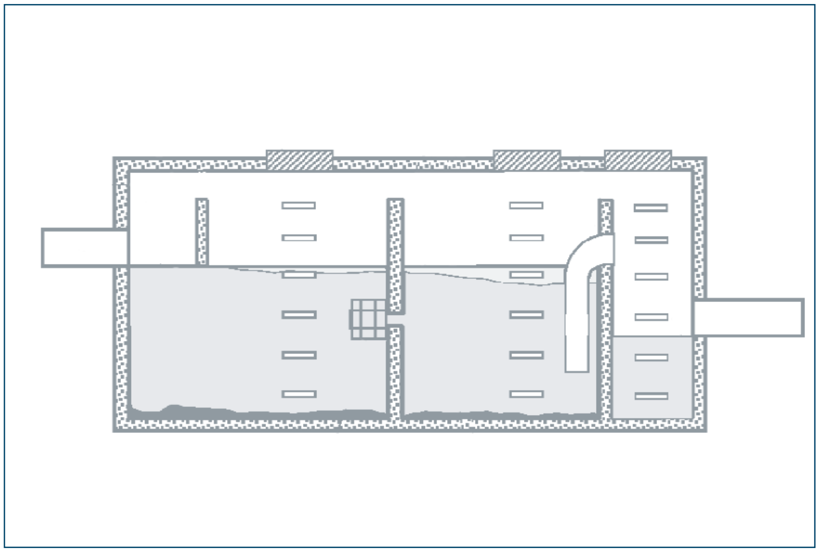
Water Environment Federation (WEF) and American Society of Civil Engineers (ASCE), *Urban Runoff Quality Management*. WEF Manual of Practice No. 23 and ASCE Manual and Report on Engineering Practice No. 87, 1998.

Oil/Particle Separators



Source: City of Knoxville, 2001.

Treatment Practice Type

Primary Treatment Practice	
Secondary Treatment Practice	●

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Partial Benefit
Phosphorus	Low or Unknown Benefit
Nitrogen	Low or Unknown Benefit
Metals	Low or Unknown Benefit
Pathogens	Low or Unknown Benefit
Floatables	Significant Benefit
Oil and Grease	Significant Benefit
Dissolved Pollutants	Low or Unknown Benefit
Runoff Volume Reduction	
Runoff Capture	Low or Unknown Benefit
Groundwater Recharge	Low or Unknown Benefit
Stream Channel Protection	Low or Unknown Benefit
Peak Flow Control	Low or Unknown Benefit

Key: ■ Significant Benefit; ■ Partial Benefit; □ Low or Unknown Benefit

Suitable Applications

Pretreatment	Significant Benefit
Treatment Train	Significant Benefit
Ultra-Urban	Significant Benefit
Stormwater Retrofits	Significant Benefit
Other	Significant Benefit

Description

Oil/particle separators, also called oil/grit separators, water quality inlets, and oil/water separators, consist of one or more chambers designed to remove trash and debris and to promote sedimentation of coarse materials and separation of free oil (as opposed to emulsified or dissolved oil) from stormwater runoff. Oil/particle separators are typically designed as off-line systems for pretreatment of runoff from small impervious areas, and therefore provide minimal attenuation of flow. Due to their limited storage capacity and volume, these systems have only limited water quality treatment capabilities. While oil/particle separators can effectively trap floatables and oil and grease, they are ineffective at removing nutrients and metals and only capture coarse sediment.

Several conventional oil/particle separator design variations exist, including:

- *Conventional gravity separators (water quality inlets)*
- *Coalescing plate (oil/water) separators*

Conventional gravity separators (also called American Petroleum Institute or API separators) typically consist of three baffled chambers and rely on gravity and the physical characteristics of oil and sediments to achieve pollutant removal. The first chamber is a sedimentation chamber where floatable debris is trapped and gravity settling of sediments occurs. The second chamber is designed primarily for oil separation, and the third chamber provides additional settling prior to discharging to the storm drain system or downstream treatment practice. Many design modifications exist to enhance system performance including the addition of orifices, inverted elbow pipes and diffusion structures. **Figures 11-S4-1** and **11-S4-2** illustrate several examples of conventional gravity separator designs.

Conventional gravity separators used for stormwater treatment are similar to wastewater oil/water separators, but have several important differences. **Figure 11-S4-3** shows a typical oil/water separator designed to treat wastewater discharges from vehicle washing and floor drains. As shown in the figure, wastewater separators commonly employ a single chamber with tee or elbow inlet and outlet pipes. The magnitude and duration of stormwater flows are typically much more variable than wastewater flows and, therefore, the single-chamber design does not provide sufficient protection against re-suspension of sediment during runoff events. Single-chamber wastewater oil/water separators should not be used for stormwater applications.

The basic gravity separator design can be modified by adding coalescing plates to increase the effectiveness of oil/water separation and reduce the size of the required unit. A series of coalescing plates, constructed of oil-attracting materials such as polypropylene and typically spaced an inch apart, attract small oil droplets which begin to concentrate until they are large enough to float to the water surface and separate from the stormwater (EPA, 1999). **Figure 11-S4-4** shows a typical coalescing plate separator design.

A number of recently developed proprietary separator designs also exist. These are addressed in the Hydrodynamic Separators section of this chapter.

Reasons for Limited Use

- *Limited pollutant removal. Cannot effectively remove soluble pollutants or fine particles.*
- *Can become a source of pollutants due to re-suspension of sediment unless maintained frequently. Maintenance often neglected ("out of sight and out of mind").*
- *Limited to relatively small contributing drainage areas.*

Suitable Applications

- *For limited removal of trash, debris, oil and grease, and sediment from stormwater runoff from relatively small impervious areas with high traffic volumes or high potential for spills such as:*
  - *Parking lots*
  - *Streets*
  - *Truck loading areas*
  - *Gas stations*
  - *Refueling areas*
  - *Automotive repair facilities*
  - *Fleet maintenance yards*
  - *Commercial vehicle washing facilities*
  - *Industrial facilities.*
- *To provide pretreatment for other stormwater treatment practices.*
- *For retrofit of existing stormwater drainage systems, particularly in highly developed (ultra-urban) areas.*

Design Considerations

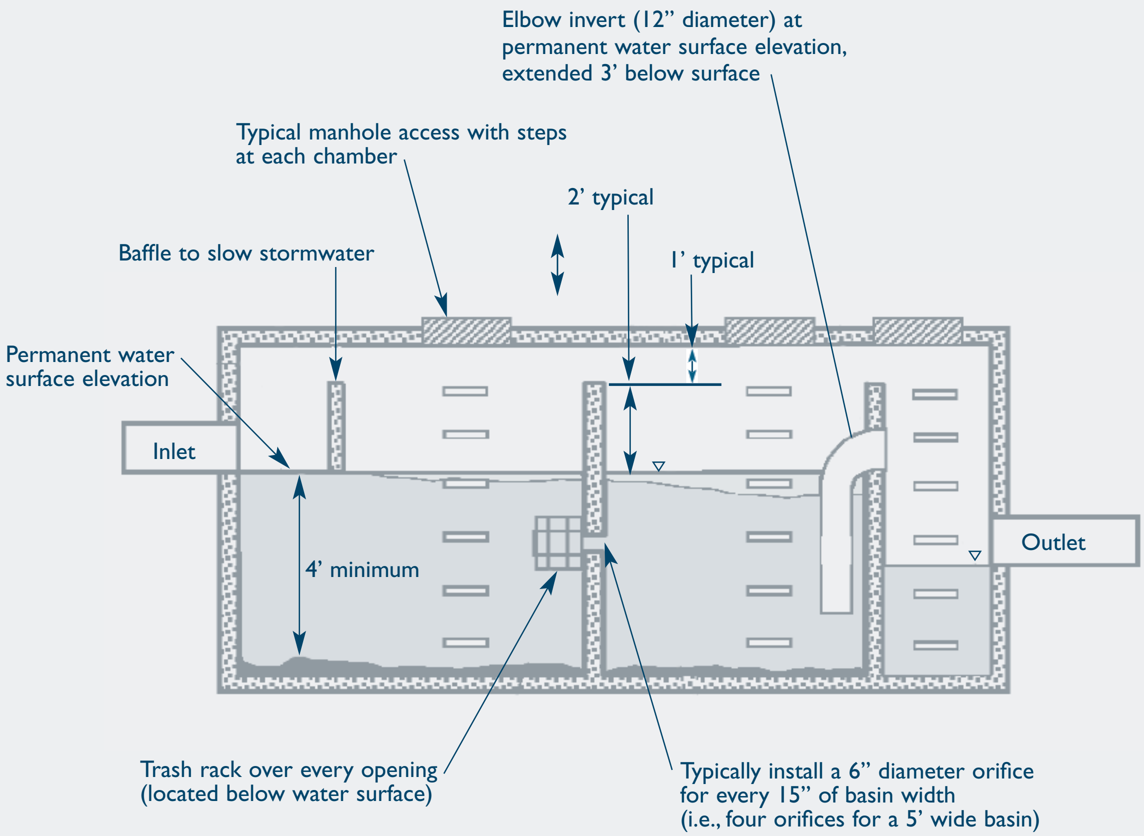
Drainage Area: The contributing drainage area to conventional oil/particle separators generally should be limited to one acre or less of impervious cover. Separators should only be used in an off-line configuration to treat the design water quality flow (peak flow associated with the design water quality volume). Upstream diversion structures can be used to divert higher flows around the separator. On-line units receive higher flows that cause increased turbulence and re-suspension of settled material (EPA, 1999).

Sizing/Design: The combined volume of the permanent pools in the chambers should be 400 cubic feet per acre of contributing impervious area. The pools should be at least 4 feet deep, and the third chamber should also be used as a permanent pool.

A trash rack or screen should be used to cover the discharge outlet and orifices between chambers. An inverted elbow pipe should be located between the second and third chambers, and the bottom of the elbow pipe should be at least 3 feet below the second chamber permanent pool. Each chamber should be equipped with manholes and access steps/ladders for maintenance and cleaning. Potential mosquito entry points should be sealed (adult female mosquitoes can use openings as small as 1/16 inch to access water for egg laying).

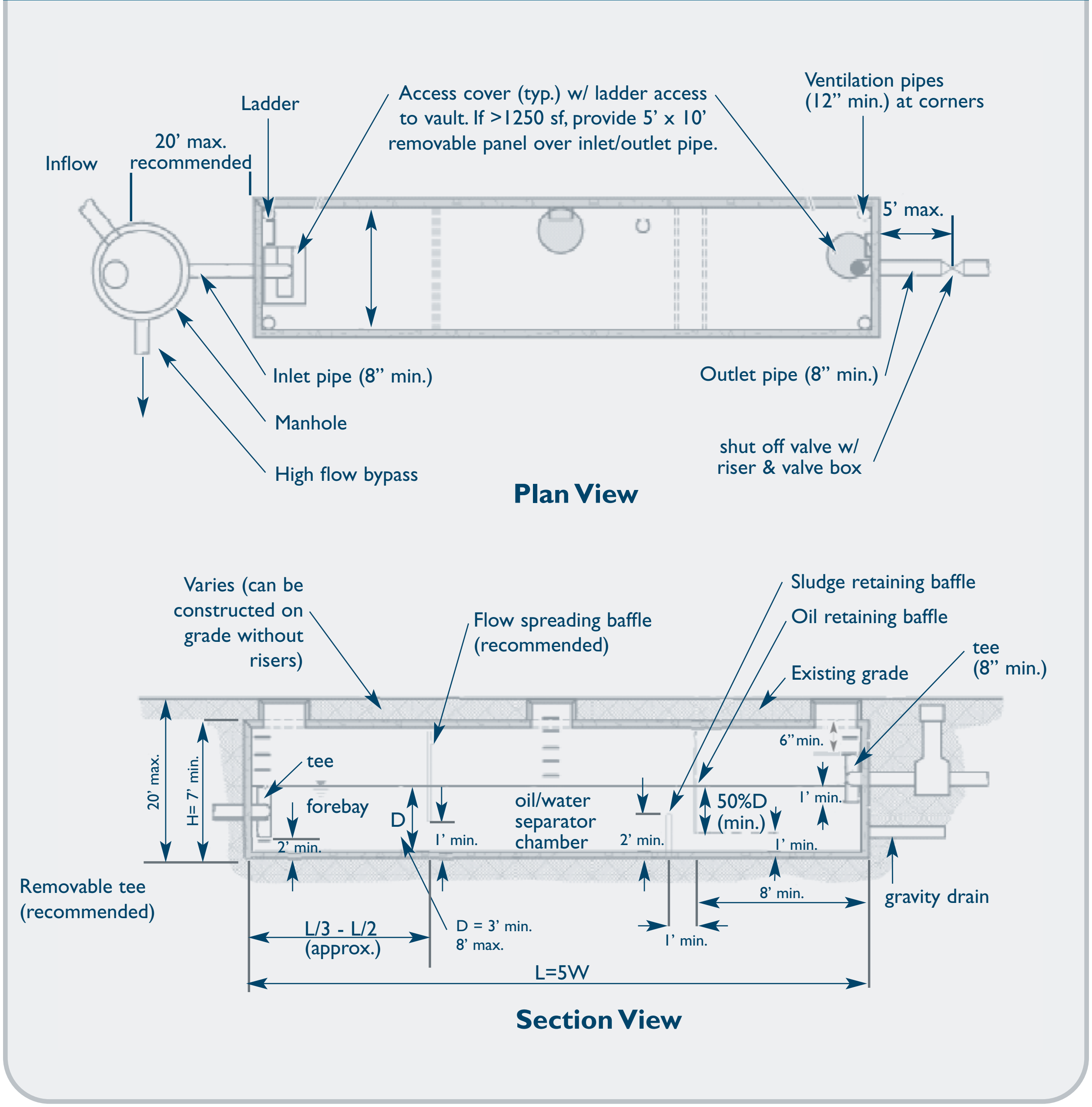
Maintenance: Maintenance is critical for proper operation of oil/particle separators. Separators that are not maintained can be significant sources of pollution. Separators should be inspected at least

Figure 11-S4-1 Example of Conventional Gravity Separator Design (Design Alternate 1)



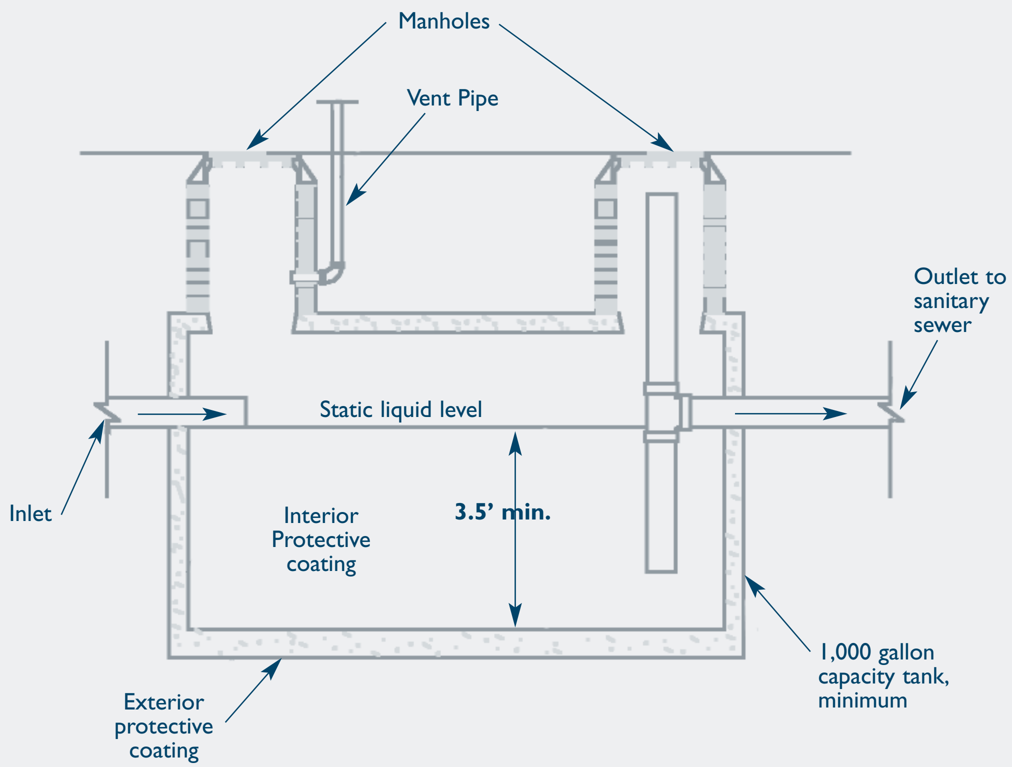
Source: City of Knoxville, 2001.

Figure 11-S4-2 Example of Conventional Gravity Separator Design (Design Alternate 2)



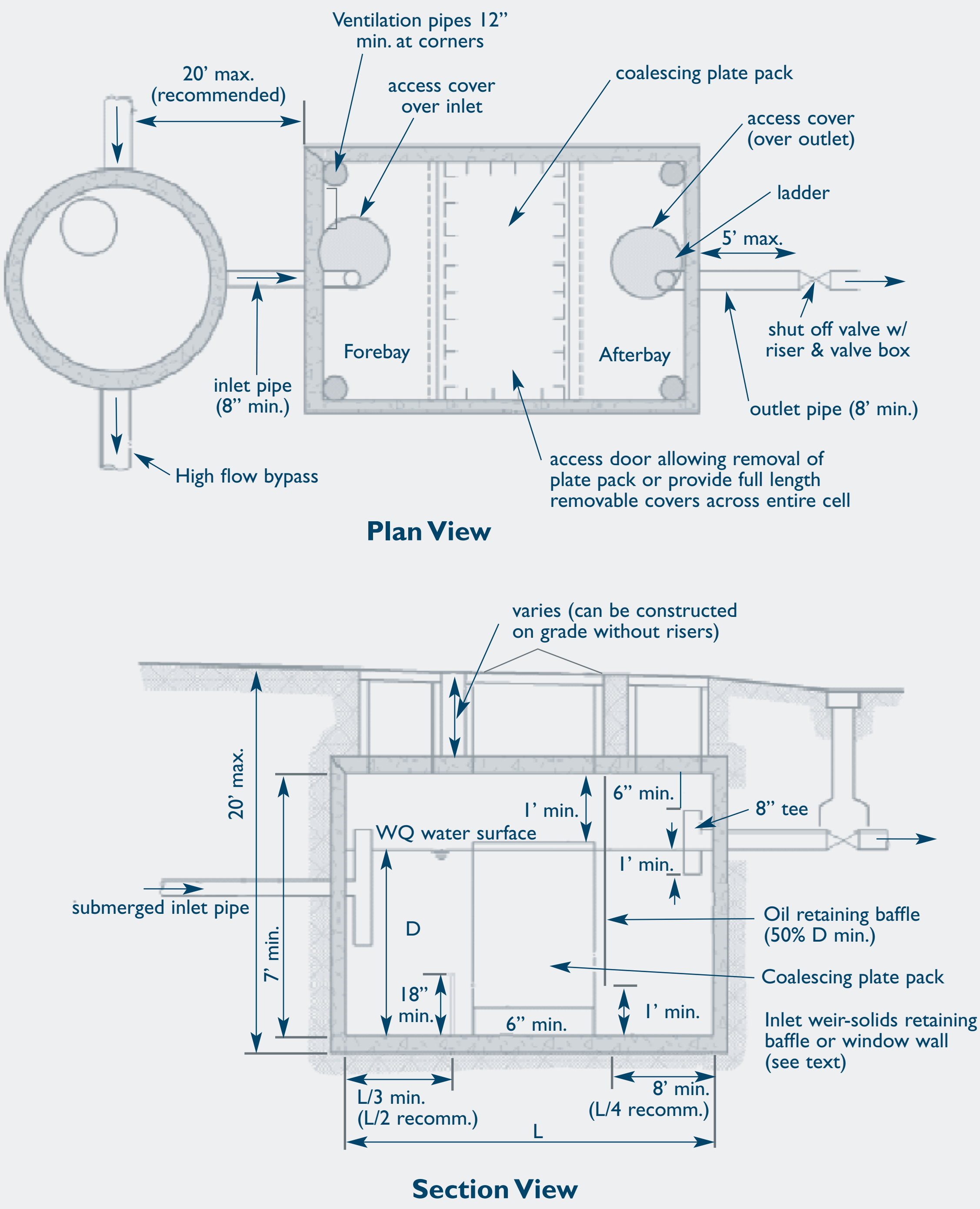
Source: Washington, 2000.

Figure 11-S4-3 Example of a Typical Wastewater Oil/Water Separator



Source: Adapted from Connecticut DEP Vehicle Maintenance Wastewater General Permit, January 2001.

Figure 11-S4-4 Example of Coalescing Plate Separator Design



Source: Washington, 2000.

monthly and typically need to be cleaned every one to six months. Typical maintenance includes removal of accumulated oil and grease, floatables, and sediment using a vacuum truck or other ordinary catch basin cleaning equipment.

Plans for oil/particle separators should identify detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance.

Sediment Disposal: Polluted water or sediment removed from separators should be properly handled and disposed of in accordance with local, state, and federal regulations. Before disposal, appropriate chemical analysis of the material should be performed to determine proper methods for storage and disposal.

References

Connecticut Department of Environmental Protection (DEP). 2001. General Permit for the Discharge of Vehicle Maintenance Wastewater. Issuance Date January 23, 2001.

City of Knoxville. 2001. Knoxville BMP Manual. City of Knoxville Engineering Department. Knoxville, Tennessee.

United States Environmental Protection Agency (EPA). 2002. National Menu of Best Management Practices for Stormwater Phase II. URL: http://www.epa.gov/npdes/menuofbmps/menu.htm, Last Modified January 24, 2002.

United States Environmental Protection Agency (EPA). 1999. Storm Water Technology Fact Sheet: Water Quality Inlets. EPA 832-F-99-029. Office of Water. Washington, D.C.

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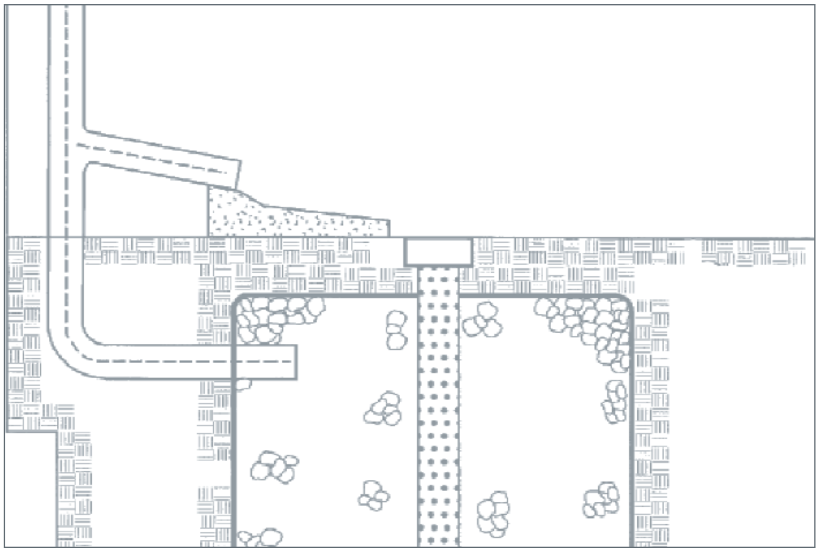
Dry Wells



Source: Adapted from Center for Watershed Protection, 2000.

Treatment Practice Type

Treatment Practice Type	
Primary Treatment Practice	
Secondary Treatment Practice	●

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Partial Benefit
Phosphorus	Partial Benefit
Nitrogen	Partial Benefit
Metals	Partial Benefit
Pathogens	Low or Unknown Benefit
Floatables	Low or Unknown Benefit
Oil and Grease	Low or Unknown Benefit
Dissolved Pollutants	Partial Benefit
Runoff Volume Reduction	
Runoff Capture	Significant Benefit
Groundwater Recharge	Significant Benefit
Stream Channel Protection	Partial Benefit
Peak Flow Control	Partial Benefit

Key: ■ Significant Benefit
■ Partial Benefit
□ Low or Unknown Benefit

Suitable Applications

Pretreatment	Low or Unknown Benefit
Treatment Train	Significant Benefit
Ultra-Urban	Low or Unknown Benefit
Stormwater Retrofits	Significant Benefit
Other	Low or Unknown Benefit

Description

Dry wells are small excavated pits filled with aggregate, which receive clean stormwater runoff primarily from building rooftops. Dry wells function as infiltration systems to reduce the quantity of runoff from a site and recharge groundwater. Dry wells treat stormwater runoff through soil infiltration, adsorption, trapping, filtering, and bacterial degradation. The use of dry wells is applicable for small drainage areas with low sediment or pollutant loadings and where soils are sufficiently permeable to allow reasonable rates of infiltration. **Figure 11-S5-1** shows a schematic of a typical dry well design. **Figure 11-S5-2** depicts an alternative precast concrete dry well design.

Reasons for Limited Use

- *Applicable to small drainage areas (one acre or less).*
- *Potential failure due to improper siting, design, construction, and maintenance.*
- *Susceptible to clogging by sediment.*
- *Risk of groundwater contamination depending on subsurface conditions, land use, and aquifer susceptibility.*
- *Not suitable for stormwater runoff from land uses or activities with the potential for high sediment or pollutant loads.*
- *Can drain wetlands or vernal pools if roof water is captured and released in another drainage area or below the wetland/vernal pool area.*

Suitable Applications

- *For infiltration of rooftop runoff that is unlikely to contribute significant loadings of sediment or pollutants (i.e., non-industrial, non-metallic roofs). Dry wells are not recommended for infiltrating parking lot runoff without pretreatment to remove sediment, hydrocarbons, and other pollutants.*
- *These systems can be installed under parking lots and other developed areas, provided that the system can be accessed for maintenance purposes.*
- *Useful in stormwater retrofit applications where space is limited and where additional runoff control is required.*
- *Where storm drains are not available and where adequate pretreatment is provided.*

Design Considerations

Dry wells are small-scale infiltration systems similar to the primary treatment infiltration practices described in previous sections of this chapter. Many of the siting, design, construction, and maintenance considerations for dry wells are similar to those of infiltration trenches, which are summarized below.

Soils: Dry wells should only be used with soils having suitable infiltration capacity (as confirmed through field testing). The minimum acceptable field-measured soil infiltration rate is 0.3 inches per hour. Field-measured soil infiltration rates should not exceed 5.0 inches per hour. This generally restricts application to soils of NRCS Hydrologic Soil Group A. Some Group B soils may be suitable if field-measured infiltration rates exceed 0.3 inches per hour. Refer to the Infiltration Practices section of this chapter for recommended field measurement techniques. One infiltration test and test pit or soil boring is recommended at the proposed location of the dry well. An observation well consisting of a well-anchored, vertical perforated PVC pipe with lockable aboveground cap should be installed to monitor system performance.

Land Use: Dry wells should only be used to infiltrate relatively clean runoff such as rooftop runoff. Dry wells should not be used to infiltrate runoff containing significant solids concentrations or concentrations of soluble pollutants that could contaminate groundwater, without adequate pretreatment. Appropriate pretreatment (e.g., filter strip, oil/particle separator, hydrodynamic device, roof washer for cisterns and rain barrels, catch basin inserts, or other secondary or primary treatment practices) should be provided to remove sediment, floatables, and oil and grease.

Drainage Area: The contributing drainage area to a dry well should be restricted to one acre or less.

Water Table/Bedrock: The bottom of the dry well should be located at least 3 feet above the seasonally high water table as documented by on-site soil testing and should be at least 4 feet above bedrock.

Size/Depth: Dry wells should be designed to completely drain the water quality volume (or larger runoff volumes for additional groundwater recharge) into the soil within 48 hours after the storm event. Dry wells should completely dewater between storms. A minimum draining time of 6 to 12 hours is recommended to ensure adequate pollutant removal. Dry wells should be equipped with overflows to handle larger runoff volumes or flows.

Miscellaneous: Dry wells should not be placed over fill materials, should be located a minimum of 10 feet from building foundations and, unless otherwise required or recommended by the DEP or the state or local health department should be located at least 75 feet away from:

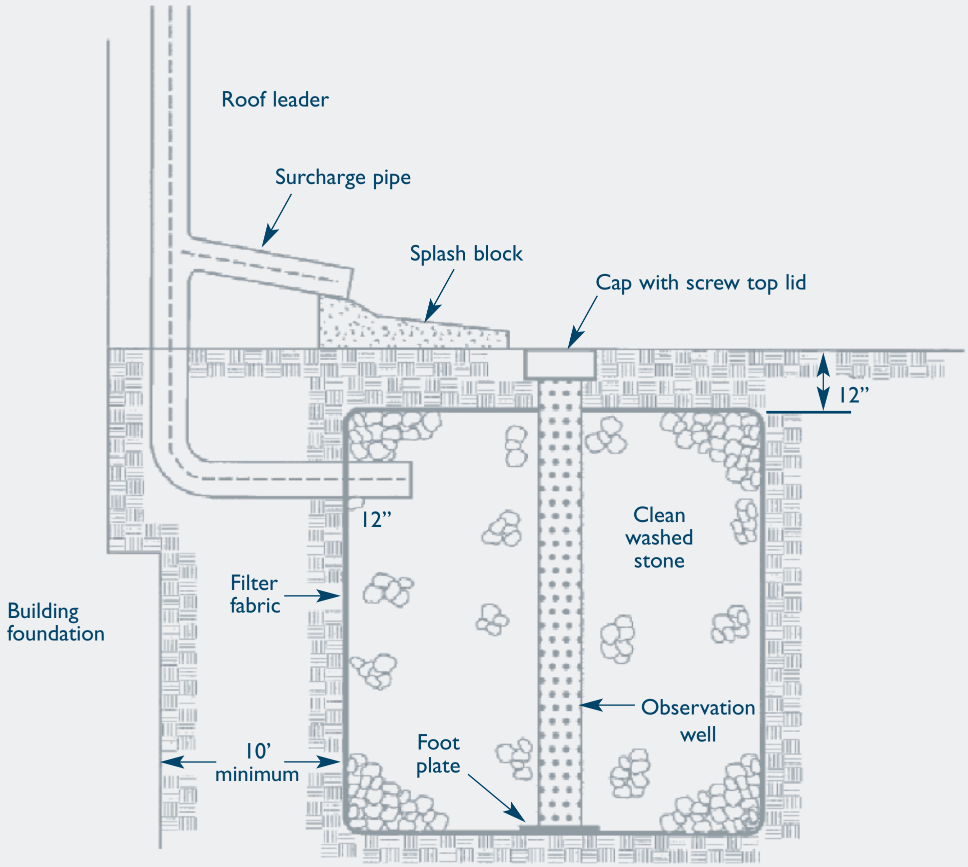
- *Drinking water supply wells*
- *Septic systems (any components)*
- *Surface water bodies*
- *Building foundations (at least 100 feet upgradient and at least 25 feet downgradient from building foundations)*

Construction: Refer to the Infiltration Practices section of this chapter for construction recommendations. The dry well should be filled with 1.5 to 3.0-inch diameter clean washed stone and be wrapped with filter fabric. The dry well should be covered by a minimum of 12 inches of soil.

Operation and Maintenance: Refer to the Infiltration Practices section of this chapter for operation and maintenance recommendations.

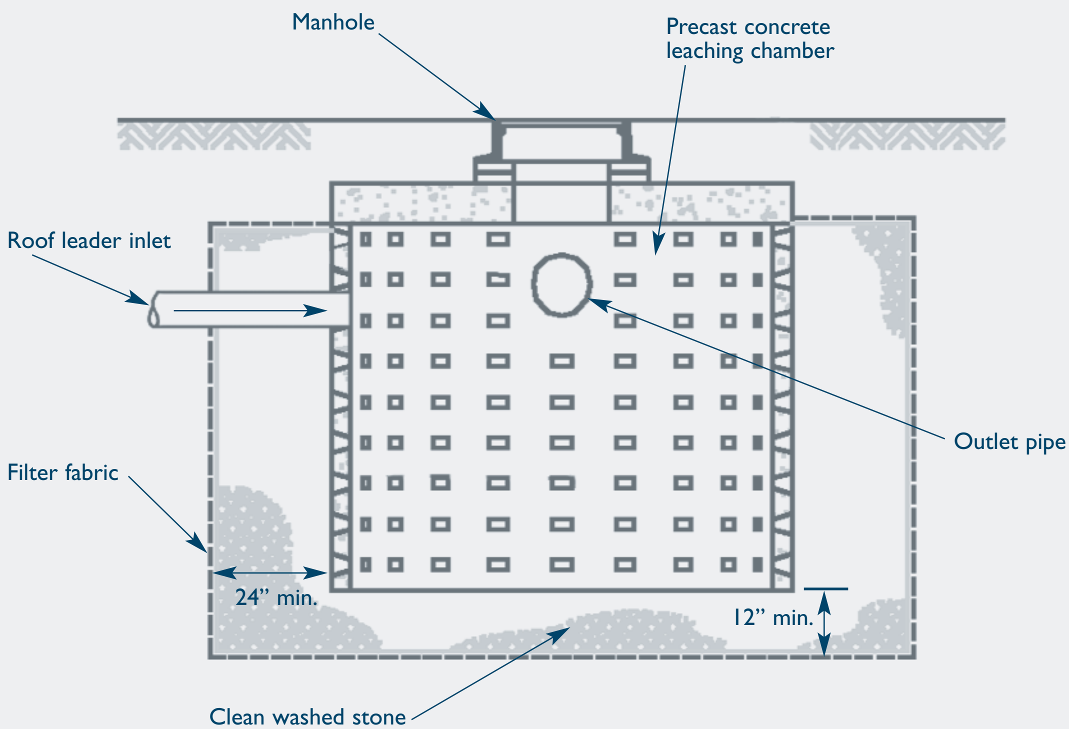
Plans for dry wells should identify detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance.

Figure 11-S5-1 Schematic of a Dry Well



Source: Adapted from Center for Watershed Protection, 2000.

Figure 11-S5-2 Precast Concrete Dry Well Design



Source: Fuss & O'Neill, Inc.

References

Center for Watershed Protection (CWP). 2000. *The Vermont Stormwater Management Handbook Technical Support Document – Public Review Draft*. Prepared For Vermont Agency of Natural Resources.

United States Environmental Protection Agency (EPA). 2002. *National Menu of Best Management Practices for Stormwater Phase II*. URL: http://www.epa.gov/npdes/menuofbmps/menu.htm, Last Modified January 24, 2002.

Permeable Pavement

Source: Nonpoint Education for Municipal Officials (NEMO).

Treatment Practice Type

Primary Treatment Practice

Secondary Treatment Practice ●

Stormwater Management Benefits

Pollutant Reduction

- Sediment — Partial Benefit
- Phosphorus — Partial Benefit
- Nitrogen — Partial Benefit
- Metals — Partial Benefit
- Pathogens — Low or Unknown Benefit
- Floatables — Low or Unknown Benefit
- Oil and Grease — Low or Unknown Benefit
- Dissolved Pollutants — Low or Unknown Benefit

Runoff Volume Reduction

- Runoff Capture — Significant Benefit
- Groundwater Recharge — Significant Benefit

Stream Channel Protection — Partial Benefit

Peak Flow Control — Partial Benefit

Key: ■ Significant Benefit
■ Partial Benefit
□ Low or Unknown Benefit

Suitable Applications

- Pretreatment — Significant Benefit
- Treatment Train — Significant Benefit
- Ultra-Urban (low traffic) — Significant Benefit
- Stormwater Retrofits — Significant Benefit
- Other — Low or Unknown Benefit

Description

Permeable pavement is designed to allow rain and snowmelt to pass through it, thereby reducing runoff from a site, promoting groundwater recharge, and filtering some stormwater pollutants. Permeable paving materials are alternatives to conventional pavement surfaces and include:

- *Modular concrete paving blocks*
- *Modular concrete or plastic lattice*
- *Cast-in-place concrete grids*
- *Soil enhancement technologies*
- *Other materials such as gravel, cobbles, wood, mulch, brick, and natural stone*

These practices increase a site's load bearing capacity and allow grass growth and infiltration (Metropolitan Council, 2001). Modular paving blocks or grass pavers consist of interlocking concrete or plastic units with spaces planted with turf or gravel for infiltration. The pavers are typically placed in a sand bed and gravel sub-base to enhance infiltration and prevent settling. Modular paving systems also include plastic lattice that can be rolled, cut to size, and filled with gravel or turfgrass. Cast-in-place concrete pavement incorporates gaps filled with soil and grass and provides additional structural capacity. Soil enhancement technologies have also been developed in which a soil amendment such as synthetic mesh is blended with a permeable soil medium to create an engineered load-bearing root zone (Metropolitan Council, 2001). Other traditional materials with varying degrees of infiltration capacity such as gravel, cobbles, wood, mulch, and stone can be used for driveways, walking trails, and other similar low traffic surfaces. **Figure 11-S6-1** illustrates examples of common permeable pavement applications.

Porous asphalt or concrete (i.e., porous pavement), which look similar to traditional pavement but are manufactured without fine materials and incorporate additional void spaces, are only recommended for certain limited applications in Connecticut due to their potential for clogging and high failure rate in cold climates. Porous pavement is only recommended for sites that meet the following criteria:

- *Low traffic applications (generally 500 or fewer average daily trips or ADT).*
- *The underlying soils are sufficiently permeable (see Design Considerations below).*
- *Road sand is not applied.*
- *Runoff from adjacent areas is directed away from the porous pavement by grading the surrounding landscape away from the site or by installing trenches to collect the runoff.*
- *Regular maintenance is performed (sweeping, vacuum cleaning).*

Reasons for Limited Use

- *Not recommended in areas with high traffic volumes (generally greater than 500 ADT).*
- *Susceptible to clogging by sediment.*
- *Does not provide significant levels of pollutant removal. Some treatment is provided by the adsorption, filtration, and microbial decomposition at the base-subgrade interface (Schueler et al., 1992).*
- *Snow removal is difficult since plows may not be used, sand application can lead to premature clogging, and salt can result in groundwater contamination.*
- *Applicable to small drainage areas.*
- *Not applicable to low permeability soils or soils prone to frost action.*
- *Potential failure due to improper siting, design, construction, and maintenance.*
- *Risk of groundwater contamination depending on subsurface conditions, land use, and aquifer susceptibility. Should not be used in public drinking water aquifer recharge areas except in certain "clean" residential settings where measures are taken to protect groundwater quality.*
- *Not suitable for land uses or activities with the potential for high sediment or pollutant loads or in areas with subsurface contamination.*
- *May not be suitable for areas that require wheelchair access due to the pavement texture.*

Suitable Applications

- *In combination with alternative site design or Low Impact Development techniques to reduce stormwater runoff volumes and pollutant loads.*
- *Low traffic (generally 500 ADT or less) areas of parking lots (i.e., overflow parking for malls and arenas), driveways for residential and light commercial use, walkways, bike paths, and patios.*
- *Roadside rights-of-way and emergency access lanes.*
- *Useful in stormwater retrofit applications where space is limited and where additional runoff control is required.*
- *In areas where snow plowing is not required.*

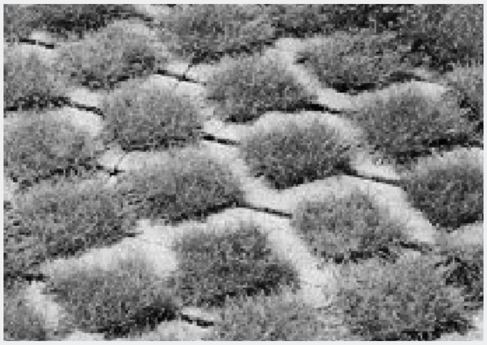
Design Considerations

Permeable pavement is a type of infiltration practice similar to the primary treatment infiltration practices described in previous sections of this chapter. Many of the siting, design, construction, and maintenance considerations for permeable pavement are similar to those of other infiltration practices. In addition, modular pavers and grids should be installed and maintained in accordance with the manufacturer's instructions. General considerations for permeable pavement are summarized below:

Soils: Permeable pavement should only be used with soils having suitable infiltration capacity as confirmed through field testing. Field-measured soil infiltration rates should be at least 0.3 inches per hour. Field-measured soil infiltration rates should not exceed 5.0 inches per hour to allow for adequate pollutant attenuation in the soil. This generally restricts application to soils of NRCS Hydrologic Soil Group A. Some Group B soils may be suitable if field-measured infiltration rates exceed 0.3 inches per hour. Refer to the Infiltration Practices section of this chapter for recommended field measurement techniques. Permeable pavement should not be used on fill soils or soils prone to frost action.

Land Use: Permeable pavement should not be used in public drinking water aquifer recharge areas or where there is a significant concern for groundwater contamination. Exceptions may include certain "clean" residential applications where measures are taken to protect groundwater quality (e.g., residential drive

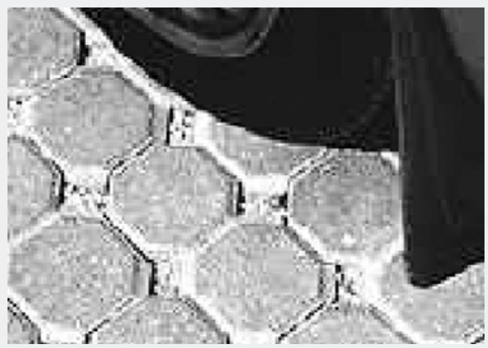
Figure 11-S6-1 Examples of Permeable Pavement Applications



Modular Concrete Pavers

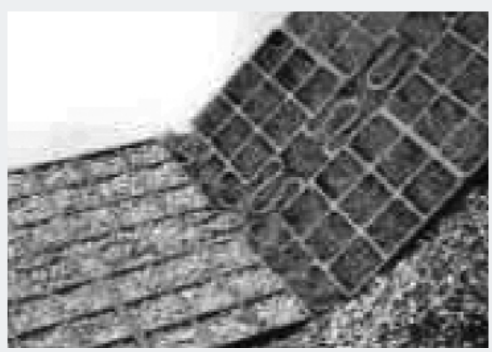
Parking Lot with Porous Surface

Overflow Parking Area



Concrete Paver Driveway

Low Use Parking Area



Plastic lattice Turf Pavement

Source: Nonpoint Education for Municipal Officials (NEMO) web site.

ways or walkways graded to drain away from the permeable pavement). Permeable pavement is not appropriate for land uses where petroleum products, greases, or other chemicals will be used, stored, or transferred. Except where recommended by local or state health departments or the Department of Environmental Protection, permeable paving materials should not be used in areas that receive significant amounts of sediment or areas that require sand and salt application for winter deicing.

Slope: Permeable pavement should not be used in areas that are steeply sloped (>15%), such as steep driveways, as this may lead to erosion of the material in the voids.

Water Table/Bedrock: The seasonally high water table as documented by on-site soil testing, should be at least 3 feet below grade. Bedrock should be at least 4 feet below grade. Except where recommended by local or state health departments or the Department of Environmental Protection, permeable pavement should be located at least 75 feet from drinking water wells.

Construction: Manufacturer's guidelines should be followed for installation. Generally, the following procedures are followed for construction of modular pavement systems:

Site Preparation

- *Site must be excavated and fine graded to the depth required by the base design.*
- *Roller pressure should be applied to compact soils.*
- *Base rock (3" to 6" of 3/4" clean gravel) is then installed and compacted to approximately 95 percent of Standard Proctor Density.*
- *A 1" sand layer is placed on top of the gravel layer and compacted.*
- *The pavers are then installed according to manufacturer's requirements.*

Planting

- *At least 1/8" to 1/4" of the paver must remain above the soil to bear the traffic load.*
- *Sod or seeding method may be used.*
- *If sod is used, the depth of backfill required will depend on the depth of the sod. Sod is laid over the pavers, watered thoroughly, and then compressed into the cells of the pavers.*
- *If grass is planted from seed, the appropriate soil should be placed in the cells, tamped into the cells, and then watered thoroughly so that the appropriate amount of paver is exposed. The soil is then ready for planting with a durable grass seed.*
- *Traffic should be excluded from the area for at least a month to allow for establishment of grass.*

Operation and Maintenance: Permeable pavement is easiest to maintain in areas where access to the pavement is limited and controlled and where pavement maintenance can be incorporated into a routine site maintenance program, such as commercial parking lots, office buildings, and institutional buildings (Pennsylvania Association of Conservation Districts et al., 1998). Turf pavers can be mowed, irrigated, and fertilized like other turf areas. However, fertilizers and other chemicals may adversely affect concrete products, and the use of such chemicals should be minimized. Pavers should be inspected once per year for deterioration and to determine if soil/vegetation loss has occurred. Soil or vegetation should be replaced or repaired as necessary. Care must be exercised when removing snow to avoid catching the snow plow on the edges of the pavers. Permeable pavement should be regularly cleared of tracked mud or sediment and leaves.

Plans for permeable pavement should identify detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance.

References

Metropolitan Council. 2001. *Minnesota Urban Small Sites BMP Manual: Stormwater Best Management Practices for Cold Climates*. Prepared by Barr Engineering Company. St. Paul, Minnesota.

Nonpoint Education for Municipal Officials (NEMO) website, URL: http://nemo.uconn.edu.

Pennsylvania Association of Conservation Districts, Keystone Chapter Soil and Water Conservation Society, Pennsylvania Department of Environmental Protection, and Natural Resources Conservation Service. 1998. *Pennsylvania Handbook of Best Management Practices for Developing Areas*. Prepared by CH2MHILL.

Schueler, T.R., Kumble, P.A., and M.A. Heraty. 1992. *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Non-Point Source Pollution in the Coastal Zone*. Department of Environmental Programs. Metropolitan Washington Council of Governments.

Vegetated Filter Strips and Level Spreaders

Source: Nonpoint Education for Municipal Officials (NEMO).

Treatment Practice Type

Primary Treatment Practice
Secondary Treatment Practice ●

Stormwater Management Benefits

Pollutant Reduction	
Sediment	▨
Phosphorus	▨
Nitrogen	▨
Metals	▨
Pathogens	□
Floatables	□
Oil and Grease	□
Dissolved Pollutants	□

Runoff Volume Reduction	
Runoff Capture	▨
Groundwater Recharge	▨

Stream Channel Protection	▨
Peak Flow Control	□

Key: ■ Significant Benefit
▨ Partial Benefit
□ Low or Unknown Benefit

Suitable Applications

Pretreatment	■
Treatment Train	■
Ultra-Urban	□
Stormwater Retrofits	■
Other	□

Description

Vegetated filter strips, also known as filter strips and grass filters, are uniformly graded vegetated surfaces (i.e., grass or close-growing native vegetation) located between pollutant source areas and downstream receiving waters or wetlands. Vegetated filter strips typically treat sheet flow directly from adjacent impervious surfaces, or small concentrated flows can be distributed along the width of the strip using a level spreader. Vegetated filter strips are designed to slow runoff velocities, trap sediment, and promote infiltration, thereby reducing runoff volumes.

Vegetated filter strips are commonly used as pretreatment prior to discharge to other filtering practices or bioretention systems. They can also be placed downgradient of stormwater outfalls equipped with outlet protection and level spreaders to reduce flow velocities and promote infiltration/filtration. Filter strips are effective when used in the outer zone of a stream buffer (see Chapter Four) to provide pretreatment of runoff from adjacent developed areas (EPA, 1999). In general, vegetated filter strips are relatively inexpensive to install, have relatively low maintenance requirements, but require large amounts of land.

Reasons for Limited Use

- *Provide limited pollutant removal. Filter strips are difficult to monitor, and therefore there is limited data on their pollutant removal effectiveness (Metropolitan Council, 2001). Little or no treatment is provided if the filter strip is short-circuited by concentrated flows.*
- *Applicable to small drainage areas.*
- *Proper maintenance required for maintaining a healthy stand of dense vegetation and preventing formation of concentrated flow.*
- *Poor retrofit option due to large land requirements.*
- *Effective only on drainage areas with gentle slopes (<15 percent).*
- *Improper grading can render the practice ineffective for pollutant removal (EPA, 2002).*

- *Not suitable for stormwater runoff from land uses or activities with the potential for high sediment or pollutant loads due to the risk of groundwater contamination or damage to vegetation.*

Suitable Applications

- *In conjunction with other stormwater management practices to treat runoff from highways, roads, and small parking lots.*
- *To infiltrate and filter runoff from residential areas such as roof downspouts, driveways, and lawns. Filter strips are relatively easy to incorporate into most residential developments.*
- *To reduce directly connected impervious areas, and thus runoff volume and peak flows.*
- *In stormwater retrofit applications where land is available. Existing outfalls may be suitable candidates for installation of level spreaders to distribute flow and reduce erosive velocities. Use of filter strips and level spreaders at large outfalls or outfalls with significant flow velocities is not recommended due to the difficulty associated with converting erosive concentrated flows into sheet flow.*
- *In conjunction with bioretention areas or stream buffer systems to provide pretreatment and reduce erosive runoff velocities.*
- *As side slopes of grass drainage channels or water quality swales, particularly where sufficient land area is available such as highway medians and shoulders.*

Design Considerations

Slope: Should be designed on slopes between 2 and 6 percent. Steeper slopes encourage the formation of concentrated flow. Flatter slopes encourage ponding and potential mosquito breeding habitat (EPA, 2002).

Soils: Should not be used on soils with high clay content due to limited infiltration, or on soils that cannot sustain grass cover.

Drainage Area: The contributing drainage area to vegetated filter strips is generally limited to one acre or less. The length of flow, rather than the drainage area, is considered to be the limiting design factor due to the formation of high-velocity concentrated flow. Without the use of a level spreader, the maximum overland flow lengths to the filter strip generally should be limited to 150 feet for pervious surfaces and 75 feet for impervious surfaces. Longer overland flow lengths are acceptable if a level spreader is used.

Water Table/Bedrock: Vegetated filter strips should be separated from seasonally high groundwater and bedrock by between 2 and 4 feet, as documented by on-site soil testing, to reduce the potential for groundwater contamination and saturated soil conditions between storms.

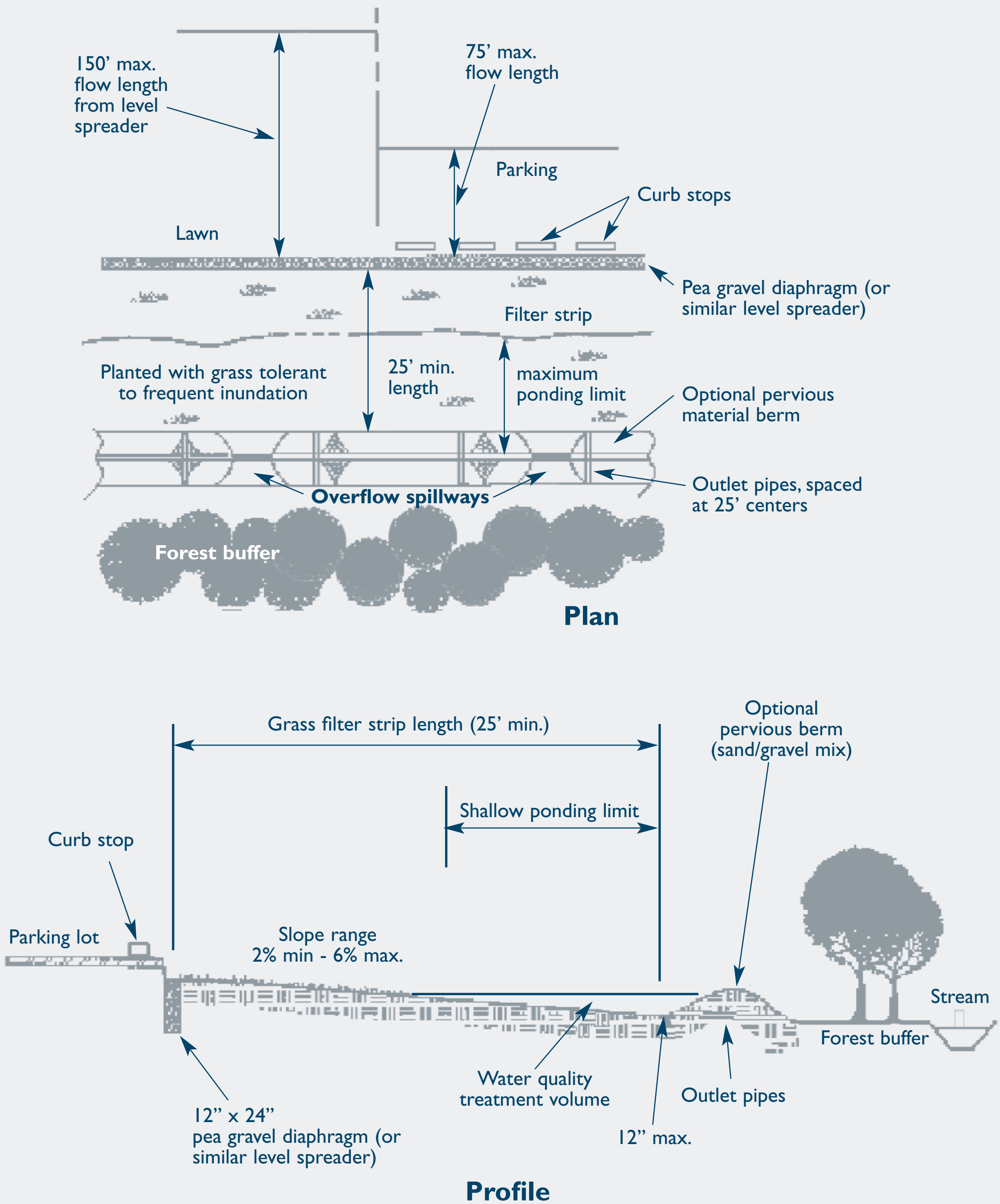
Size: The top and toe of slope should be designed as flat as possible to encourage sheet flow and infiltration. The filter strip should be at least 25 feet long and generally as wide as the area draining to the strip. The filter strip should be designed to drain within 24 hours after a storm. The design flow depth should not exceed 0.5 inches. The design should incorporate a bypass system to accommodate flows from larger storms (i.e., 2 year storm or larger). A pervious berm of sand or gravel can be added at the toe of the slope to enhance pollutant removal. In this design, the filter strip should be sized to provide surface storage of the water quality volume behind the berm. **Figure 11-S7-1** shows a common filter strip design for the edge of a lawn or parking lot.

Vegetation: Grasses should be selected to withstand relatively high flow velocities and both wet and dry conditions.

Level Spreader: A level spreader should be used at the top of slope to distribute overland flow or concentrated runoff (see the maximum overland flow length guidelines above) evenly across the entire length of the filter strip. Many level spreader design variations exist, including level trenches (e.g., pea gravel diaphragms, see **Figure 11-S7-1**), curbing, concrete weirs, etc. The key to any level spreader design is a continuous overflow elevation along the entire width of the filter strip. Velocity dissipation (i.e., riprap) may be required for concentrated flows. **Figure 11-S7-2** and **Figure 11-S7-3** show examples of two concrete level spreader designs.

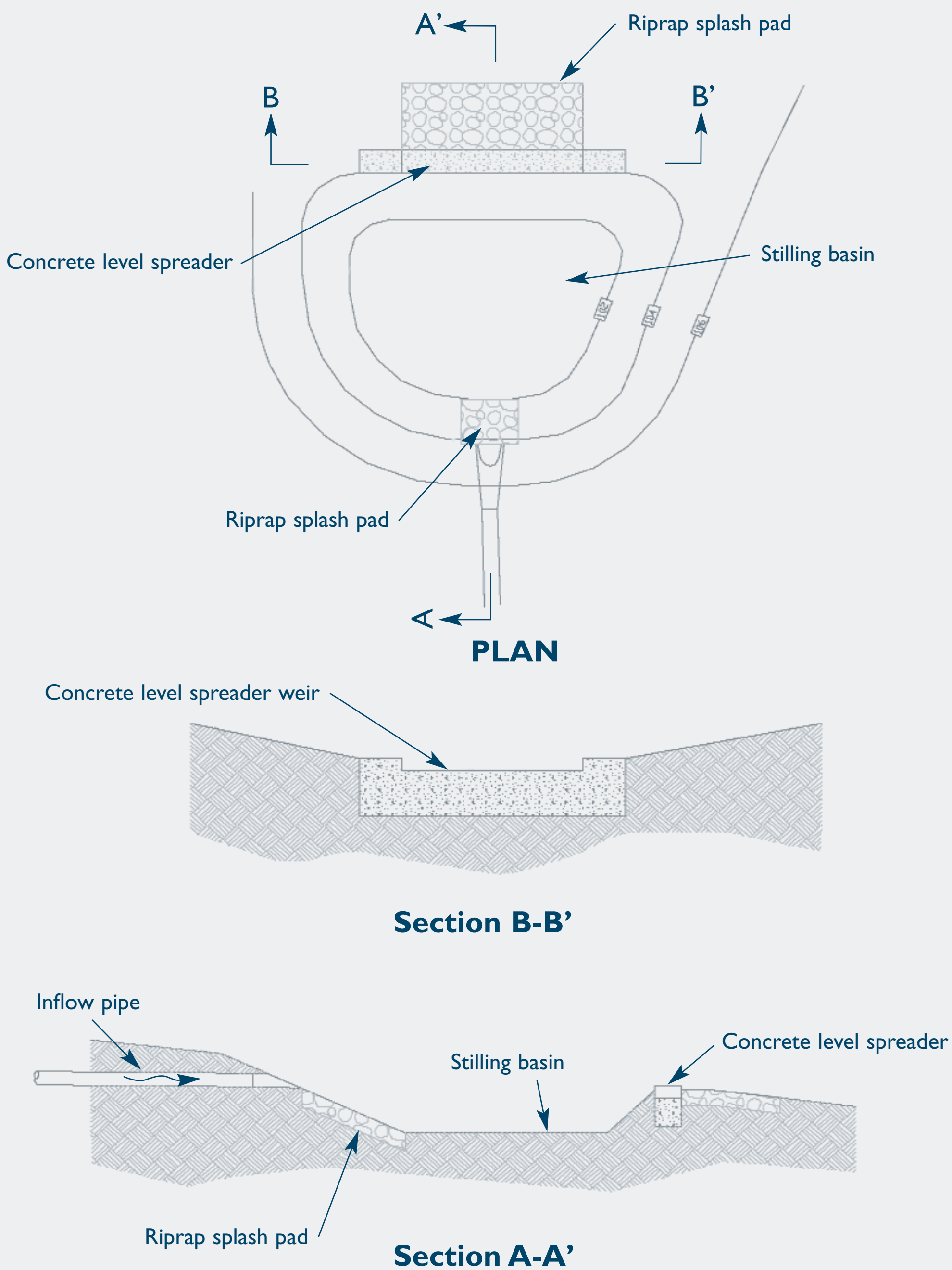
Construction: Proper grading is essential to establish sheet flow from the level spreader and throughout the filter strip. Soil stabilization measures should be implemented until permanent vegetation is established.

Figure 11-S7-1 Vegetated Filter Strip Schematic



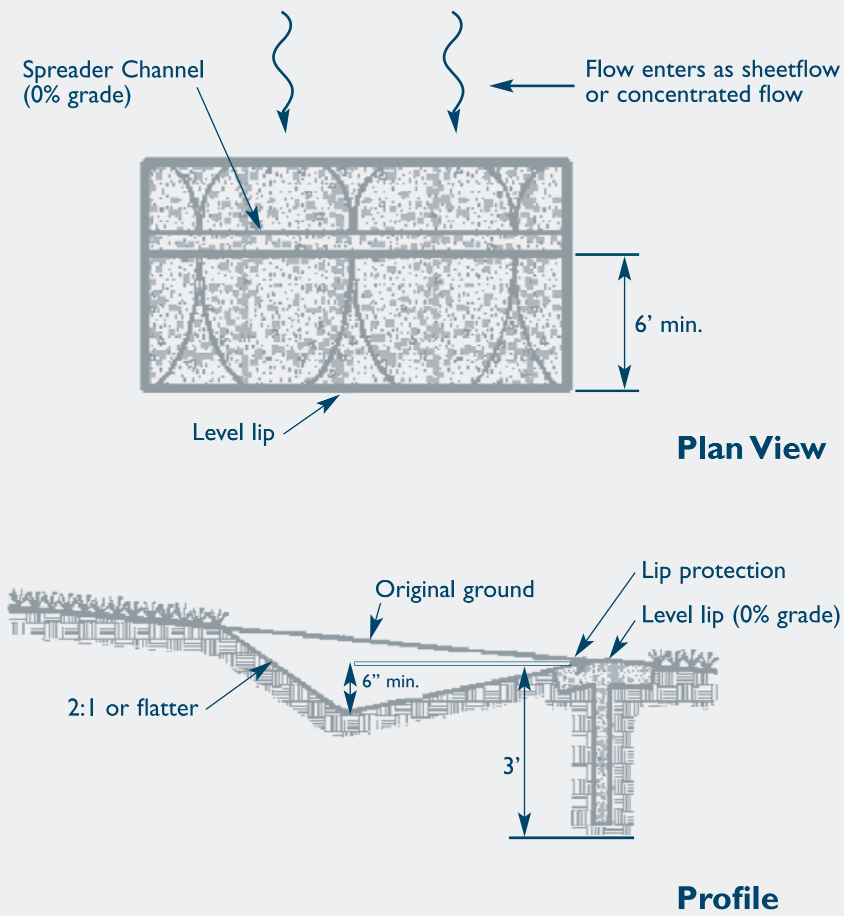
Source: Adapted from Claytor and Schueler, 1996.

Figure 11-S7-2 Concrete Level Spreader Design Example 1



Source: Fuss & O'Neill, Inc.

Figure 11-S7-3 Concrete Level Spreader Design Example 2



Source: Adapted from Center for Watershed Protection, 2000.

Operation and Maintenance: Regular maintenance is critical for the effectiveness of filter strips, especially to ensure that flow does not short-circuit the system. Semi-annual inspections are recommended during the first year (and annually thereafter), including inspection of the level spreader for sediment buildup and inspection of the vegetation for erosion, bare spots, and overall health. Regular, frequent mowing of the grass to a height of 3 to 4 inches is required. Sediment should be removed from the toe of slope or level spreader, and bare spots should be reseeded as necessary.

Plans for vegetated filter strips and level spreaders should identify detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance.

References

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

Metropolitan Council. 2001. *Minnesota Urban Small Sites BMP Manual: Stormwater Best Management Practices for Cold Climates*. Prepared by Barr Engineering Company. St. Paul, Minnesota.

New York State Department of Environmental Conservation (NYDEC). 2001. *New York State Stormwater Management Design Manual*. Prepared by Center for Watershed Protection. Albany, New York.

United States Environmental Protection Agency (EPA). 1999. *Preliminary Data Summary of Urban Storm Water Best Management Practices*. EPA 821-R99-012.

United States Environmental Protection Agency (EPA). 2002. *National Menu of Best Management Practices for Stormwater Phase II*. URL: http://www.epa.gov/npdes/menuofbmps/menu.htm, Last Modified January 24, 2002.

Grass Drainage Channels

Source: Nonpoint Education for Municipal Officials (NEMO).

Treatment Practice Type

Primary Treatment Practice	
Secondary Treatment Practice	●

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Partial Benefit
Phosphorus	Partial Benefit
Nitrogen	Partial Benefit
Metals	Partial Benefit
Pathogens	Low or Unknown Benefit
Floatables	Low or Unknown Benefit
Oil and Grease	Low or Unknown Benefit
Dissolved Pollutants	Partial Benefit
Runoff Volume Reduction	
Runoff Capture	Low or Unknown Benefit
Groundwater Recharge	Partial Benefit
Stream Channel Protection	Partial Benefit
Peak Flow Control	Low or Unknown Benefit

Key: Significant Benefit; Partial Benefit; Low or Unknown Benefit

Suitable Applications

Pretreatment	Significant Benefit
Treatment Train	Low or Unknown Benefit
Ultra-Urban (low traffic)	Low or Unknown Benefit
Stormwater Retrofits	Low or Unknown Benefit
Other	Significant Benefit

Description

Grass drainage channels are traditional vegetated open channels designed for conveyance rather than water quality treatment. Drainage channels provide limited pollutant removal through filtration by grass or other vegetation, sedimentation, biological activity in the grass/soil media, as well as limited infiltration if underlying soils are pervious. However, their primary function is to provide non-erosive conveyance, typically up to the 10-year frequency design flow. Grass drainage channels are typically trapezoidal, triangular, or parabolic in shape and are designed based on peak flow rate rather than a water quality volume approach.

Drainage channels are commonly incorporated into highway and road drainage systems, but can also be used in place of traditional curb and gutter drainage systems in residential and commercial areas to enhance pollutant removal and to provide limited groundwater recharge and runoff volume reduction. **Figure 11-S8-1** depicts a schematic of a typical grass drainage channel.

Reasons for Limited Use

- *Provide limited pollutant removal.*
- *Require more maintenance than traditional curb and gutter drainage systems.*
- *May be impractical in areas with very flat grades, steep topography, or poorly drained soils (Metropolitan Council, 2001).*
- *Large area requirements for highly impervious sites.*

Suitable Applications

- *For runoff conveyance.*
- *As pretreatment in conjunction with other stormwater management practices.*
- *Can replace traditional curb and gutter drainage system for new development or stormwater retrofits.*
- *Linear nature makes drainage channels ideal for highway and residential road runoff, as well as industrial parks and institutional areas.*

Design Considerations

Specific design criteria and procedures for grass drainage channels are beyond the scope of this Manual. Grass drainage channels should be designed in accordance with established open channel flow principles and accepted stormwater drainage design practice, as described in the following recommended references:

- *Connecticut Department of Transportation (ConnDOT),* Connecticut Department of Transportation Drainage Manual, *October 2000.*
- *Connecticut Council on Soil and Water Conservation and the Connecticut Department of Environmental Protection,* 2001 Connecticut Guidelines for Soil Erosion and Sediment Control, DEP Bulletin 34, *2001.*
- *USDA Soil Conservation Service,* National Engineering Field Manual, *Natural Resources Conservation Service, Washington, D.C., 1988.*

Some general design considerations include:

- *For enhanced water quality performance, provide sufficient channel length to retain the water quality volume in the system for at least 10 minutes (using a check dam if necessary), and limit the water quality peak flow to 1 foot per second and a depth of no greater than 4 inches (i.e., the height of the grass). However, most of the pollutant reduction in grass drainage channels has been shown to occur in the first 65 feet of the channel (Walsh et al., 1997). Longer channels designed solely for water quality improvement may not be cost effective.*
- *For enhanced pollutant removal, design the channel side slopes to serve as vegetated filter strips by accepting sheet flow runoff. Pollutant removal that occurs across the channel side slopes (i.e., vegetated filter strip) can exceed the pollutant removal that occurs down the longitudinal length of the channel, particularly for highway medians with side slopes of 25 feet or longer (Walsh et al., 1997).*
- *Design the channel to ensure non-erosive velocities for the soil type and vegetation condition of the channel (see* ***Connecticut Guidelines for Soil Erosion and Sediment Control*** *for maximum permissible velocities).*
- *Design the channel with sufficient capacity and conveyance for the 10-year frequency storm event.*
- *Native grasses are preferred for enhanced biodiversity, wildlife habitat, and drought tolerance. Grass species should be sod-forming, resistant to frequent inundation, rigid and upright in high flows, and salt tolerant if located along a roadway. Wetland species may be used for the bottom of a wet swale. The following grasses perform well in an open channel environment:*
    - *Red Fescue (Festuca rubra)*
    - *Tall Fescue (Festuca arundinacea)*
    - *Redtop (Agrostis alba)*
    - *Smooth Bromegrass (Bromus inermis)*
    - *Reed Canarygrass (Phalaris arundinacea L.).*

References

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

Connecticut Department of Transportation (DOT). 2000. *Connecticut Department of Transportation Drainage Manual.*

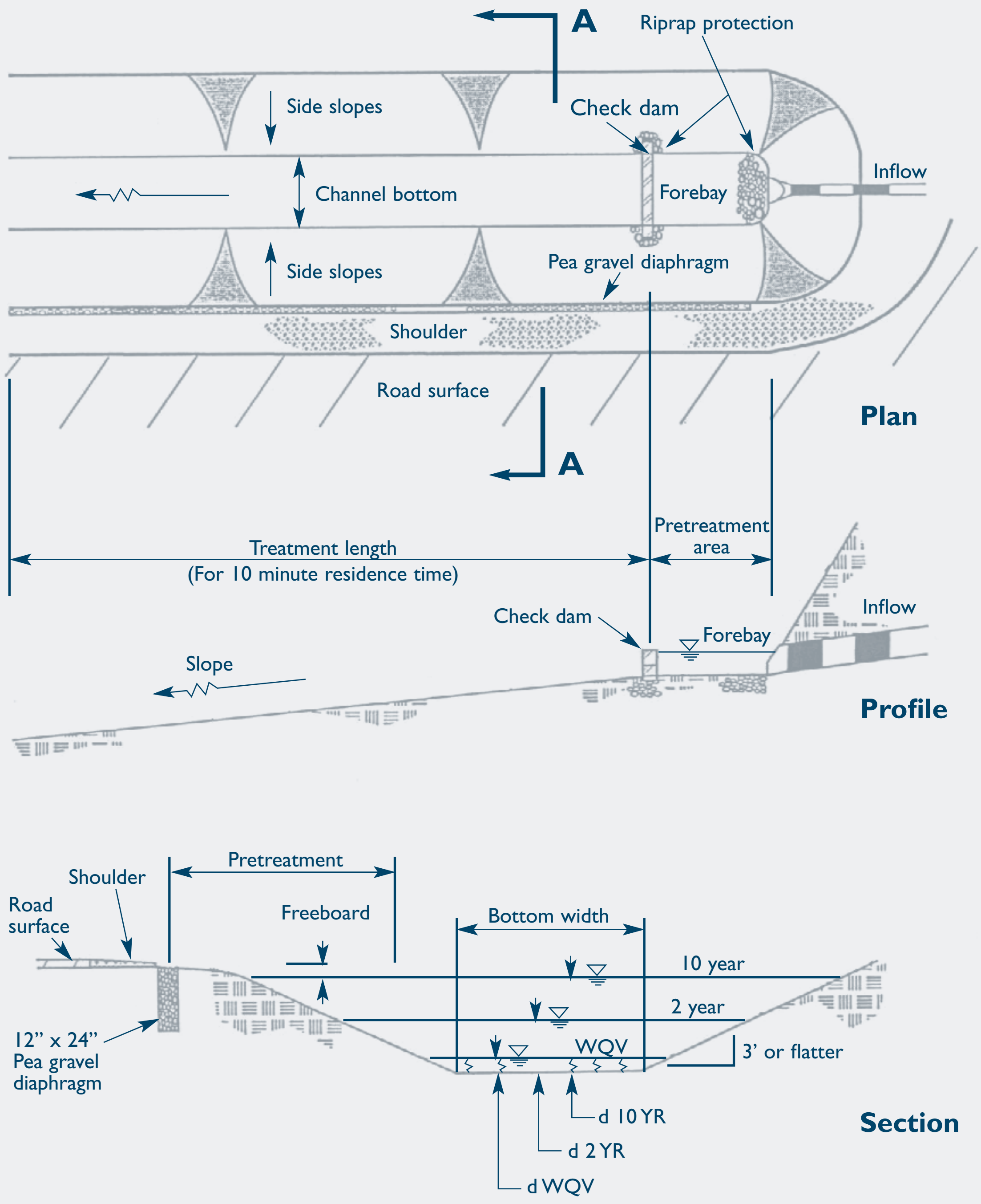
Connecticut Council on Soil and Water Conservation and the Connecticut Department of Environmental Protection. 2002. *2001 Connecticut Guidelines for Soil Erosion and Sediment Control*, DEP Bulletin 34.

Metropolitan Council. 2001. *Minnesota Urban Small Sites BMP Manual: Stormwater Best Management Practices for Cold Climates*. Prepared by Barr Engineering Company. St. Paul, Minnesota.

USDA Soil Conservation Service. 1988. National Engineering Field Manual. Natural Resources Conservation Service. Washington, D.C.

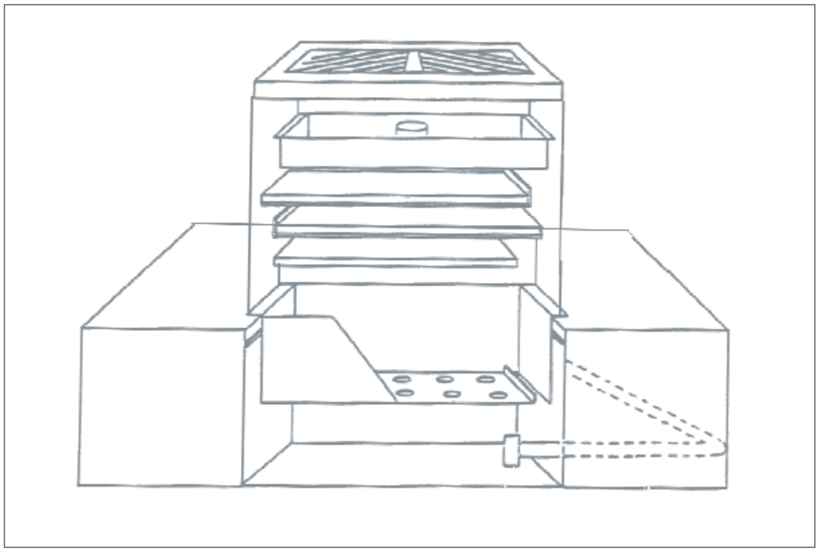
Walsh, P. M., Barrett, M.E., Malina, J.F., and R. Charbeneau. 1997. *Use of Vegetative Controls for Treatment of Highway Runoff.* Center for Research in Water Resources. Bureau of Engineering Research. University of Texas at Austin. Austin, TX.

Figure 11-S8-1 Schematic of a Grass Drainage Channel



Source: Adapted from Center for Watershed Protection, 2000.

Catch Basin Inserts



Source: City of Knoxville, 2001.

Treatment Practice Type

Primary Treatment Practice
Secondary Treatment Practice ●

Stormwater Management Benefits

Pollutant Reduction

Sediment	▣
Phosphorus	□
Nitrogen	□
Metals	▣
Pathogens	□
Floatables	▣
Oil and Grease	▣
Dissolved Pollutants	□

Runoff Volume Reduction

Runoff Capture	□
Groundwater Recharge	□

Stream Channel Protection	□
Peak Flow Control	□

Key: ■ Significant Benefit
▣ Partial Benefit
□ Low or Unknown Benefit

Suitable Applications

Pretreatment	■
Treatment Train	■
Ultra-Urban	■
Stormwater Retrofits	■
Other	□

Description

Catch basin inserts are a general category of proprietary devices that have been developed in recent years to filter runoff entering a catch basin. Catch basin inserts function similarly to media filters, but on a much smaller scale. Catch basin inserts typically consist of the following components:

- *A structure (e.g. screened box, tray, basket,) which contains a pollutant removal medium*
- *A means of suspending the structure in a catch basin*
- *A filter medium such as sand, carbon, fabric, bag, etc.*
- *A primary inlet and outlet for the stormwater*
- *A secondary outlet for bypassing flows that exceed design flow.*

(Washington, 2000). The two basic varieties of catch basin inserts include filter trays and filter fabric. The tray design consists of a series of trays, with the top tray serving as an initial sediment trap, and the underlying trays composed of media filters. The filter fabric design uses filter fabric as the filter media for pollutant removal. Depending on the insert medium, solids, organics (including oils), and metals can be removed. However, due to their small volume, catch basin inserts have very limited retention times and require frequent cleaning or replacement to be effective. **Figure 11-S9-1** and **Figure 11-S9-2** illustrate several examples of generic catch basin insert designs.

Reasons for Limited Use

- *Limited peer-reviewed performance data available. (See Chapter Six for a description of the recommended evaluation criteria and protocols for consideration of these technologies as primary treatment practices.)*

- *Require frequent maintenance and replacement. Can become a source of pollutants unless maintained frequently.*
- *Susceptible to clogging. Can aggravate flooding when clogged.*
- *Do not provide peak flow attenuation, runoff volume reduction, or groundwater recharge.*

Suitable Applications

- *To provide pretreatment for other stormwater treatment practices.*
- *For retrofit of existing conventional catch basins that lack sumps or have undersized sumps.*
- *May be considered in specialized small drainage applications such as industrial sites for specific target pollutants where clogging of the medium will not be a problem.*
- *As temporary sediment control devices and pretreatment at construction sites.*
- *For oil control at small sites where the insert medium has sufficient hydrocarbon loading capacity and rate of removal, and the solids and debris will not prematurely clog the insert.*
- *Can be used in unpaved areas for inlet protection.*

Design Considerations

Due to the proprietary nature of these products, catch basin inserts should be designed according to the manufacturer's recommendations. Some general design considerations for catch basin inserts include:

High Flow Bypass: A high flow bypass or other design feature to allow stormwater runoff into the drain system in the event of clogging and runoff in excess of the water quality design flow to bypass the system without danger of local flooding.

Maintenance: Should be inspected and maintained in accordance with manufacturer's recommendations. Since catch basin inserts require frequent inspection and maintenance, they should only be used where a full-time maintenance person is on-site.

Plans for catch basin inserts should identify detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance.

Sediment Disposal: Sediment removed from catch basin inserts should be properly handled and disposed in accordance with local, state, and federal regulations. Before disposal, appropriate chemical analysis of the material should be performed to determine proper methods for storage and disposal.

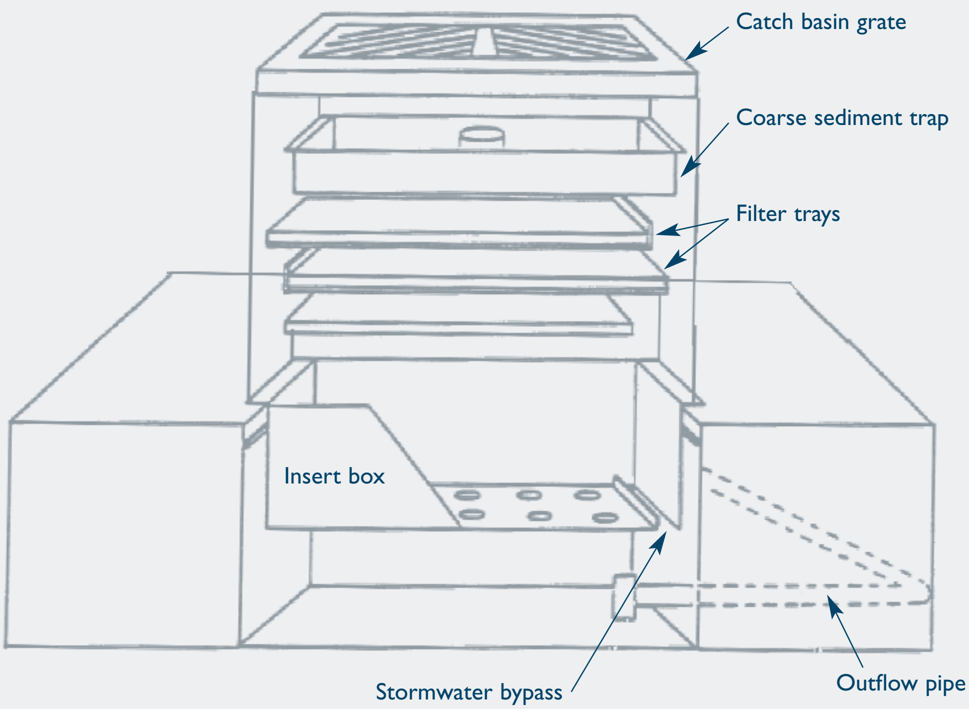
References

City of Knoxville. 2001. *Knoxville BMP Manual*, City of Knoxville Engineering Department. Knoxville, Tennessee.

United States Environmental Protection Agency (EPA). 2002. *National Menu of Best Management Practices for Stormwater Phase II*. URL: http://www.epa.gov/npdes/menuofbmps/menu.htm, Last Modified January 24, 2002.

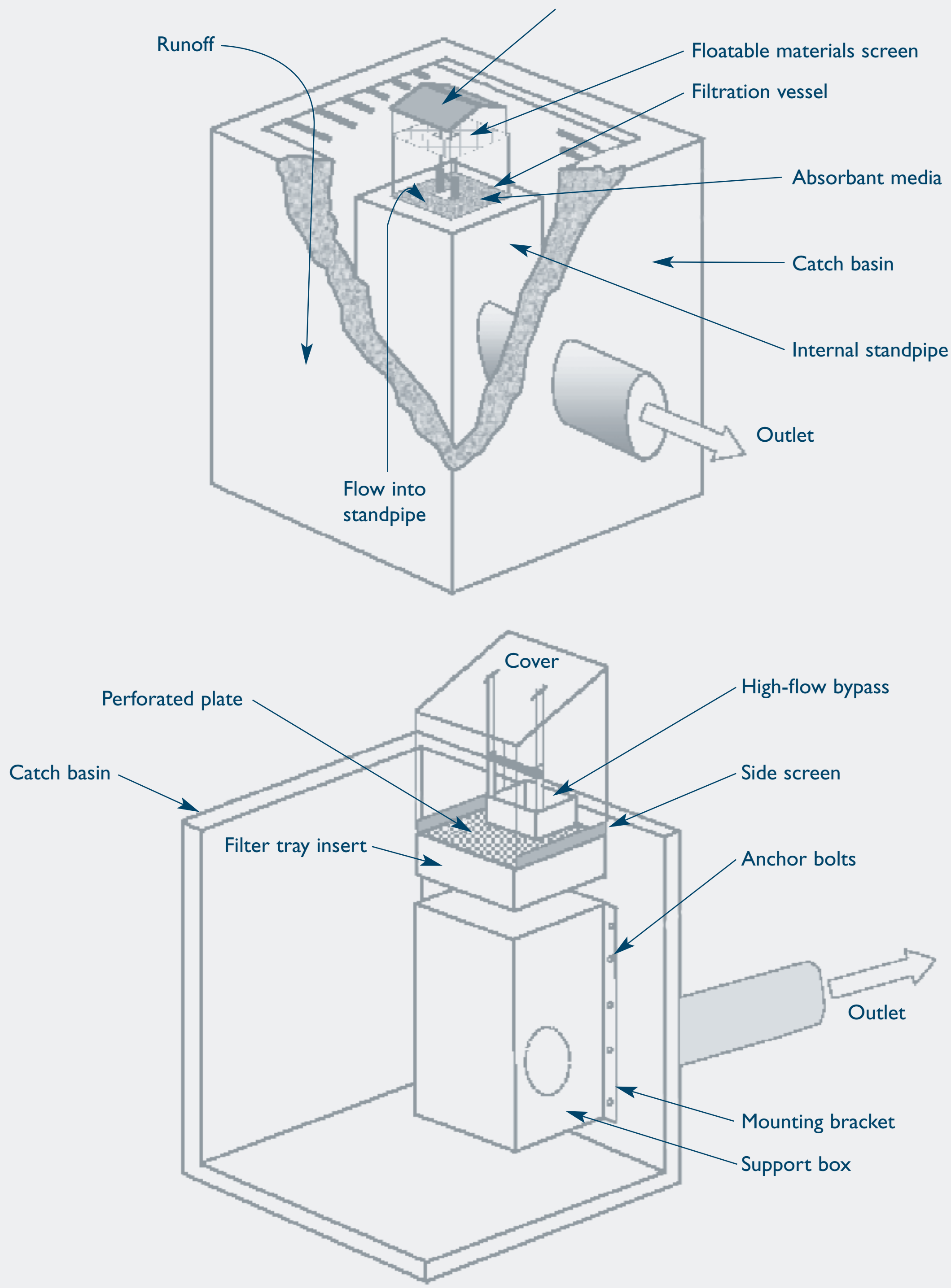
Washington State Department of Ecology (Washington). 2000. *Stormwater Management Manual for Western Washington, Final Draft*. Olympia, Washington.

Figure 11-S9-1 Example of Tray-Type Catch Basin Insert



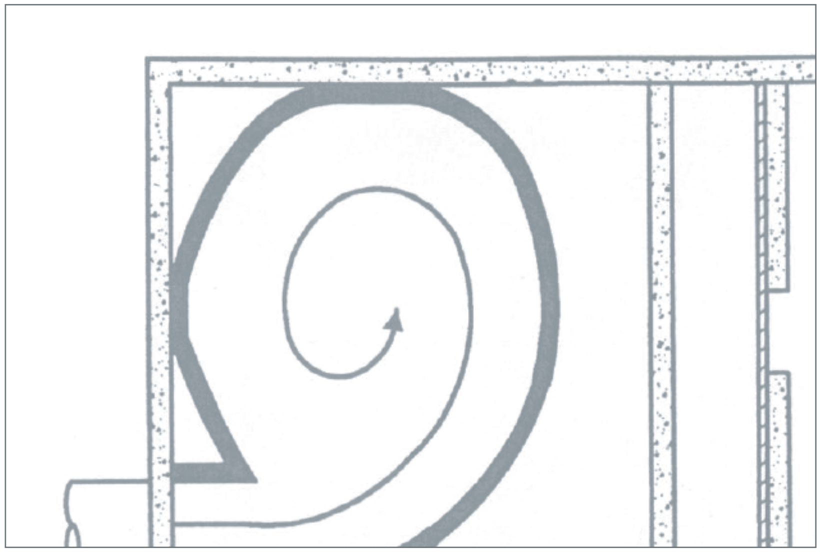
Source: City of Knoxville, 2001.

Figure 11-S9-2 Example of Clog-Resistant Media Filter Catch Basin Inserts



Source: City of Knoxville, 2001.

Hydrodynamic Separators



Source: Adapted from City of Knoxville, 2001.

Treatment Practice Type

Primary Treatment Practice
Secondary Treatment Practice ●

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Significant Benefit
Phosphorus	Partial Benefit
Nitrogen	Partial Benefit
Metals	Partial Benefit
Pathogens	Low or Unknown Benefit
Floatables	Significant Benefit
Oil and Grease	Significant Benefit
Dissolved Pollutants	Low or Unknown Benefit
Runoff Volume Reduction	
Runoff Capture	Low or Unknown Benefit
Groundwater Recharge	Low or Unknown Benefit
Stream Channel Protection	Low or Unknown Benefit
Peak Flow Control	Low or Unknown Benefit

Key: ■ Significant Benefit
Partial Benefit
Low or Unknown Benefit

Suitable Applications

Pretreatment	Significant Benefit
Treatment Train	Significant Benefit
Ultra-Urban	Significant Benefit
Stormwater Retrofits	Significant Benefit
Other (Industrial applications)	Significant Benefit

Description

This group of stormwater treatment technologies includes a wide variety of proprietary devices that have been developed in recent years. These devices, also known as swirl concentrators, are modifications of traditional oil/particle separators that commonly rely on vortex-enhanced sedimentation for pollutant removal. They are designed to remove coarse solids and large oil droplets and consist primarily of cylindrical-shaped devices that are designed to fit in or adjacent to existing stormwater drainage systems (Washington, 2000). In these structures, stormwater enters as tangential inlet flow into the cylindrical structure. As the stormwater spirals through the chamber, the swirling motion causes the sediments to settle by gravity, removing them from the stormwater (EPA, 2002). Some devices also have compartments or chambers to trap oil and other floatables. **Figure 11-S10-1** shows several examples of common hydrodynamic separator designs (no endorsement of any particular product is intended).

Although swirl concentration is the most common technology used in hydrodynamic separators, others use circular screening systems or engineered cylindrical sedimentation. Circular screened systems use a combination of screens, baffles, and inlet and outlet structures to remove debris, large particle total suspended solids, and large oil droplets. Structures using engineered cylindrical sedimentation use an arrangement of internal baffles and an oil and sediment storage compartment. Other proprietary technologies incorporate an internal high flow bypass with a baffle system in a rectangular structure to simulate plug flow operation. When properly engineered and tested, these systems can also be an improvement over conventional oil/particle separators and offer removal efficiencies similar to swirl chamber technologies. Sorbents can also be added to these structures to increase removal efficiency (Washington, 2000).

Reasons for Limited Use

- *Limited peer-reviewed performance data. Some independent studies suggest only moderate pollutant removal. (See Chapter Six for a description of the recommended evaluation criteria and protocols* *for consideration of these technologies as primary treatment practices).*

- *Cannot effectively remove soluble pollutants or fine particles.*
- *Can become a source of pollutants due to re-suspension of sediment unless maintained regularly. Maintenance often neglected ("out of sight and out of mind").*

Suitable Applications

- *Where higher sediment and pollutant removal efficiencies are required over a range of flow conditions, as compared to conventional oil/particle or oil/grit separators.*
- *For limited removal of trash, debris, oil and grease, and sediment from stormwater runoff from relatively small impervious areas with high traffic volumes or high potential for spills such as:*
  - *Parking lots*
  - *Streets*
  - *Truck loading areas*
  - *Gas stations*
  - *Refueling areas*
  - *Automotive repair facilities*
  - *Fleet maintenance yards*
  - *Commercial vehicle washing facilities*
  - *Industrial facilities*
- *To provide pretreatment for other stormwater treatment practices.*
- *For retrofit of existing stormwater drainage systems, particularly in highly developed (ultra-urban) areas where larger conventional treatment practices are not feasible or where aboveground treatment practices are not an option.*

Design Considerations

Due to the proprietary nature of these products, hydrodynamic separators should be designed according to the manufacturer's recommendations. Some general design considerations for these devices include:

Drainage Area: The recommended maximum contributing drainage area to individual devices varies by manufacturer, model, etc.

Sizing/Design: In most instances, hydrodynamic separators should be used in an off-line configuration to treat the design water quality flow (peak flow associated with the design water quality volume). Upstream diversion structures can be used to bypass higher flows around the device. Sizing based on flow rate allows these devices to provide treatment within a much smaller area than conventional volume-based stormwater treatment practices such as ponds, wetlands, and infiltration practices. Potential mosquito entry points should be sealed (adult female mosquitoes can use openings as small as 1/16 inch to access water for egg laying). To avoid funneling amphibians into treatment chambers, where they are killed, Hydrodynamic separators should be used in conjunction with Cape Cod curbing or other similar curbing that allows amphibians to climb.

Performance: Performance is dependent on many variables such as particle size, sediment concentration, water temperature, and flow rate. Hydrodynamic separators should be sized and compared based on performance testing of comparable size particles, influent concentrations, and testing protocols. Comparative performance testing that establishes a performance curve over the full operating range of the technology should be considered a prerequisite to any meaningful performance based sizing.

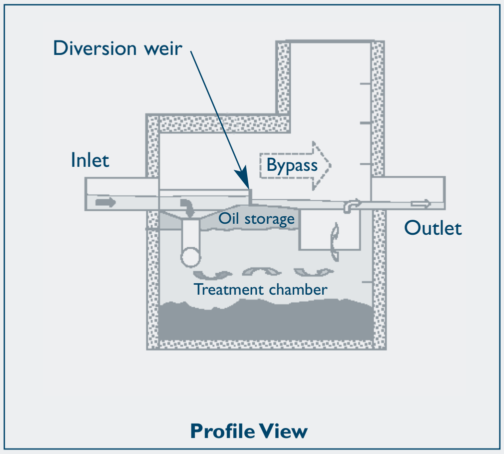
Maintenance: Frequent inspection and cleanout is critical for proper operation of hydrodynamic separators. Structures that are not maintained can be significant sources of pollution. Recommended maintenance requirements and schedules vary with manufacturer, but in general these devices need to be cleaned quarterly. Typical maintenance includes removal of accumulated oil and grease, floatables, and sediment using a vacuum truck or other ordinary catch basin cleaning equipment.

Design plans for hydrodynamic separators should identify detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance.

Sediment Disposal: Polluted water or sediment removed from these devices should be properly handled and disposed in accordance with local, state, and federal regulations. Before disposal, a detailed chemical analysis of the material should be performed to determine proper methods for storage and disposal.

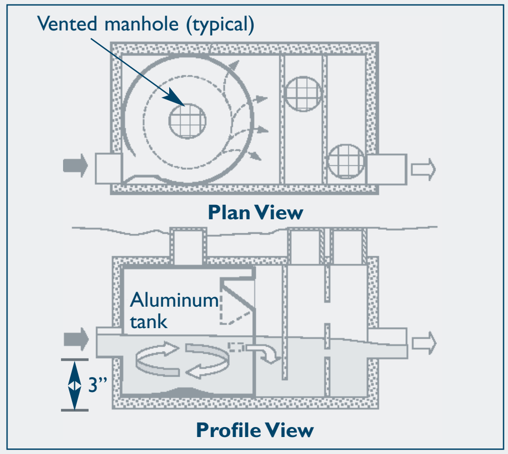
Figure 11-S10-1 Examples of Common Hydrodynamic Separator Designs

Design Example 1



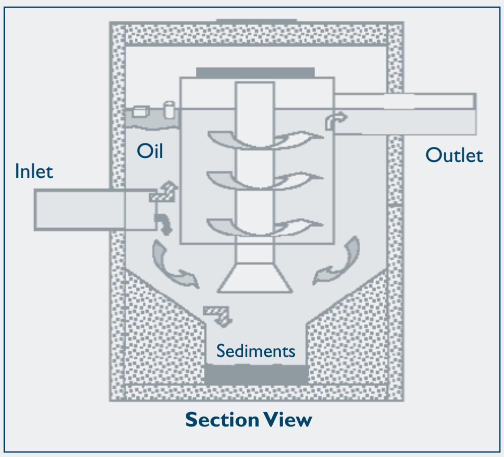
Profile View

Design Example 2



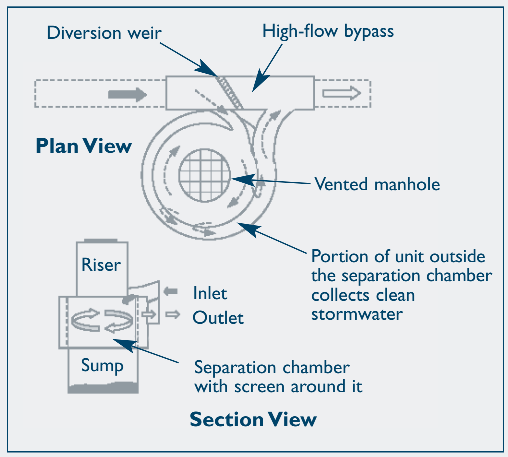
Profile View

Design Example 3



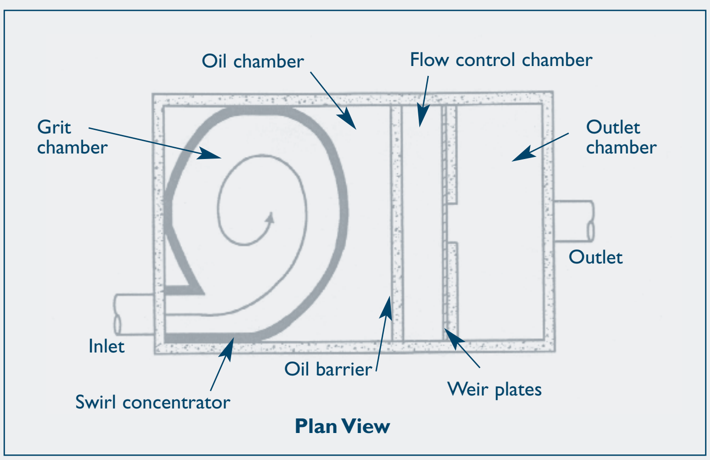
Section View

Design Example 4



Section View

Design Example 5



Plan View

Source: Adapted from City of Knoxville, 2001.

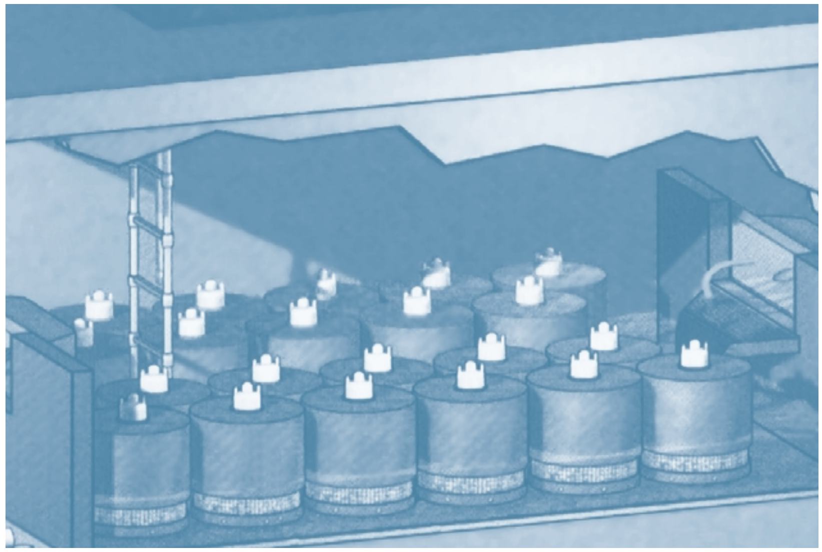
References

City of Knoxville. 2001. *Knoxville BMP Manual.* City of Knoxville Engineering Department, Knoxville, Tennessee.

United States Environmental Protection Agency (EPA). 2002. *National Menu of Best Management Practices for Stormwater Phase II*. URL: http://www.epa.gov/npdes/menuofbmps/menu.htm, Last Modified January 24, 2002.

Washington State Department of Ecology (Washington). 2000. *Stormwater Management Manual for Western Washington, Final Draft*. Olympia, Washington.

Media Filters



Source: Adapted from Stormwater Management, Inc.

Treatment Practice Type

Treatment Practice Type	
Primary Treatment Practice	
Secondary Treatment Practice	●

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Partial Benefit
Phosphorus	Partial Benefit
Nitrogen	Partial Benefit
Metals	Partial Benefit
Pathogens	Partial Benefit
Floatables	Partial Benefit
Oil and Grease	Partial Benefit
Dissolved Pollutants	Partial Benefit
Runoff Volume Reduction	
Runoff Capture	Low or Unknown Benefit
Groundwater Recharge	Low or Unknown Benefit
Stream Channel Protection	Low or Unknown Benefit
Peak Flow Control	Low or Unknown Benefit

Key: ■ Significant Benefit; ■ Partial Benefit; □ Low or Unknown Benefit

Suitable Applications

Pretreatment	Significant Benefit
Treatment Train	Significant Benefit
Ultra-Urban	Significant Benefit
Stormwater Retrofits	Significant Benefit
Other (Industrial applications)	Significant Benefit

Description

Media filters are an evolution of fixed bed sand filtration technology. In this type of treatment practice, media is placed within filter cartridges that are typically enclosed in underground concrete vaults. Stormwater is passed through the media, which traps particulates and/or soluble pollutants. Various materials may be used as filter media including pleated fabric, activated charcoal, perlite, amended sand and perlite mixes, and zeolite. Selection of filter media is largely a function of the pollutants targeted for removal. Pretreatment prior to the filter media is typically necessary for stormwater with high total suspended solids, hydrocarbon, and debris loadings that may cause clogging and premature filter failure (Washington, 2000). Maintenance requirements for filter media include sediment removal and replacement of media cartridges. **Figure 11-S11-1** shows an example of a common media filter design (no endorsement of any particular product is intended).

Reasons for Limited Use

- *Limited peer-reviewed performance data available. (See Chapter Six for a description of the recommended evaluation criteria and protocols for consideration of these technologies as primary treatment practices).*
- *Require frequent maintenance and replacement. Can become a source of pollutants unless maintained frequently.*
- *Susceptible to clogging. Pretreatment is required for high solids and/or hydrocarbon loadings and debris that could cause premature failure due to clogging.*

Suitable Applications

- *Specialized applications such as industrial sites for specific target pollutants (i.e., organics, heavy metals, and soluble nutrients) that are not easily removed by other conventional treatment practices.*

- *For retrofit of existing stormwater drainage systems, particularly in highly developed (ultra-urban) areas where larger conventional treatment practices are not feasible or where aboveground treatment practices are not an option.*
- *For pretreatment or as part of a stormwater treatment train in conjunction with other stormwater management practices.*

Design Considerations

Due to the proprietary nature of these products, media filters should be designed according to the manufacturer's recommendations. Some general design considerations for media filters include:

Sizing/Design: Media filters should primarily be used in an off-line configuration to treat either the design water quality volume or the design water quality flow (peak flow associated with the design water quality volume). Upstream diversion structures or bypass systems built into the unit are used to bypass higher flows around the device. The size and number of filter cartridges are determined based upon the anticipated solids loading rate and design water quality flow. Filter media are selected based on pollutants of concern. Potential mosquito entry points should be sealed (adult female mosquitoes can use openings as small as 1/16 inch to access water for egg laying).

Maintenance: Frequent inspection and cleanout is critical for proper operation of media filters. Structures that are not maintained can be significant sources of pollution. Manufacturer's operation and maintenance guidelines should be followed to maintain design flows and pollutant removals. Typical maintenance includes removal of accumulated oil and grease, floatables, and sediment from the filter chamber and replacement of the filter cartridges.

Plans for media filters should identify detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance.

Sediment Disposal: Polluted water or sediment removed from these devices should be properly handled and disposed in accordance with local, state, and federal regulations. Before disposal, a detailed chemical analysis of the material should be performed to determine proper methods for storage and disposal.

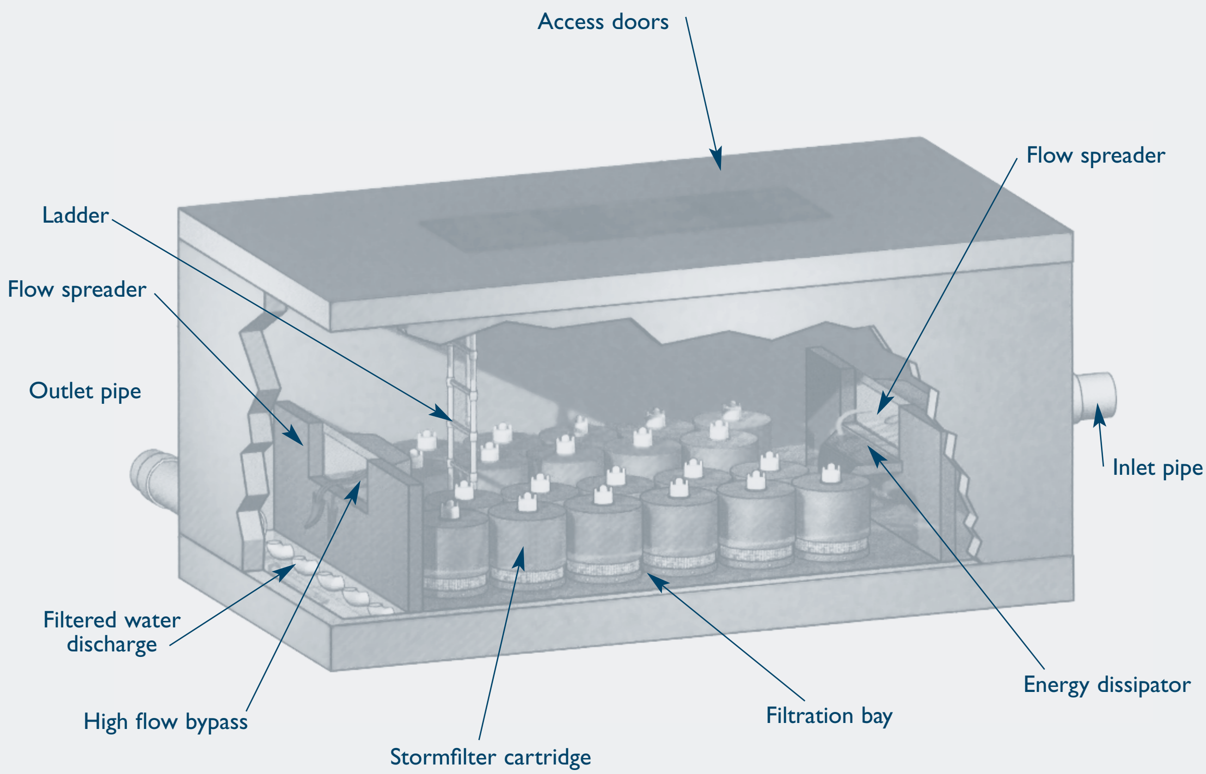
References

Stormwater Management Inc.,
URL: http://www.stormwatermgt.com/.

United States Environmental Protection Agency (EPA). 2002. *National Menu of Best Management Practices for Stormwater Phase II.* URL: http://www.epa.gov/npdes/menuofbmps/menu.htm, Last Modified January 24, 2002.

Washington State Department of Ecology (Washington). 2000. *Stormwater Management Manual for Western Washington, Final Draft.* Olympia, Washington.

Figure 11-S11-1 Typical Media Filter Design



Source: Adapted from Stormwater Management, Inc.

Underground Infiltration Systems

Source: CULTEC, Inc.

Treatment Practice Type

Practice	
Primary Treatment Practice	
Secondary Treatment Practice	●

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Partial Benefit
Phosphorus	Partial Benefit
Nitrogen	Partial Benefit
Metals	Partial Benefit
Pathogens	Low or Unknown Benefit
Floatables	Low or Unknown Benefit
Oil and Grease	Low or Unknown Benefit
Dissolved Pollutants	Partial Benefit

Runoff Volume Reduction	
Runoff Capture	Significant Benefit
Groundwater Recharge	Significant Benefit

Stream Channel Protection	Significant Benefit
Peak Flow Control	Significant Benefit

Key: ■ Significant Benefit; ■ Partial Benefit; □ Low or Unknown Benefit

Suitable Applications

Pretreatment	Low or Unknown Benefit
Treatment Train	Significant Benefit
Ultra-Urban	Significant Benefit
Stormwater Retrofits	Significant Benefit
Other	Low or Unknown Benefit

Description

A number of underground infiltration systems, including premanufactured pipes, vaults, and modular structures, have been developed as alternatives to infiltration trenches and basins for space-limited sites and stormwater retrofit applications. Similar to traditional infiltration trenches and basins, these systems are designed to capture, temporarily store, and infiltrate the water quality volume over several days. These devices are typically designed as off-line systems, but can also be used to retain and infiltrate larger runoff volumes. Performance of underground infiltration systems varies by manufacturer and system design. These systems are currently considered secondary treatment practices due to limited field performance data, although pollutant removal efficiency is anticipated to be similar to that of infiltration trenches and basins. **Figure 11-S12-1** shows several examples of common underground infiltration systems.

Reasons for Limited Use

- *Limited available monitoring data and undocumented field longevity.*
- *Potential failure due to improper siting, design (including adequate pretreatment), construction, and maintenance.*
- *Susceptible to clogging by sediment.*
- *Risk of groundwater contamination depending on subsurface conditions, land use, and aquifer susceptibility.*
- *Not suitable for stormwater runoff from land uses or activities with the potential for high sediment or pollutant loads.*

Suitable Applications

- *As an alternative to traditional infiltration trenches and basins for space-limited sites. These systems can be installed under parking lots and other developed areas, provided that the system can be accessed for maintenance purposes.*

- *Useful in stormwater retrofit applications or as part of a stormwater treatment train to provide additional groundwater recharge and storage volume to attenuate peak flows.*

Design Considerations

The materials of construction, configuration, and layout of underground infiltration systems vary considerably depending on the system manufacturer. Specific design criteria and specifications for these systems can be obtained from system manufacturers or vendors. General design elements common to most of these systems are summarized below. The reader should refer to the Infiltration Practices section of this chapter for additional information on siting, design, construction, and maintenance considerations.

Siting: Underground infiltration systems are generally applicable to small development sites (typically less than 10 acres) and should be installed in locations that are easily accessible for routine and non-routine maintenance. These systems should not be located in areas or below structures that cannot be excavated in the event that the system needs to be replaced. Similar to infiltration trenches and basins, underground infiltration systems should only be used with soils having suitable infiltration capacity (as confirmed through field testing) and for land uses, activities, or areas that do not pose a risk of groundwater contamination.

Pretreatment: Appropriate pretreatment (e.g., oil/particle separator, hydrodynamic device, catch basin inserts, or other secondary or primary treatment practices) should be provided to remove sediment, floatables, and oil and grease.

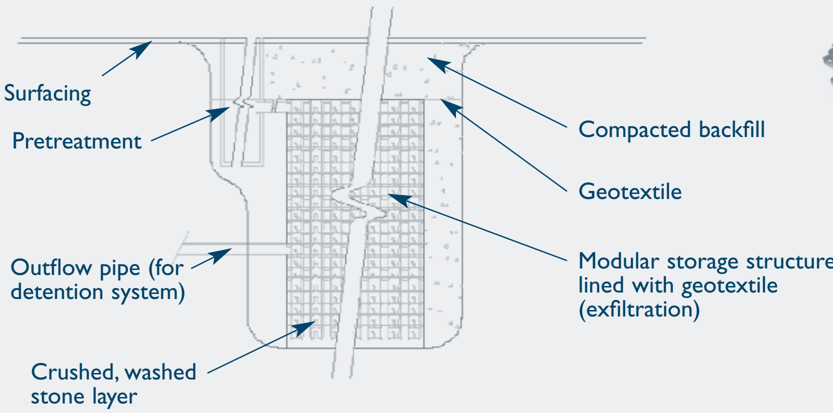
Design Volume: Underground infiltration structures should be designed as off-line practices to infiltrate the entire water quality volume. A flow bypass structure should be located upgradient of the infiltration structure to convey high flows around the structure.

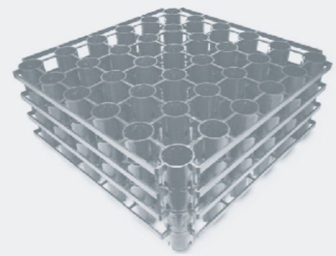
Draining Time: Infiltration structures should be designed to completely drain the water quality volume into the soil within 48 hours after the storm event and completely dewater between storms. A minimum draining time of 6 hours is recommended to ensure adequate pollutant removal. Standing water for longer than 5 days can lead to potential mosquito-breeding problems. Potential mosquito entry points should be sealed (adult female mosquitoes can use openings as small as 1/16 inch to access water for egg laying).

Infiltration Rate: The minimum acceptable field-measured soil infiltration rate is 0.3 inches per hour. Field-measured soil infiltration rates should not exceed 5.0 inches per hour. This generally restricts application to soils of NRCS Hydrologic Soil Group A. Some Group B soils may be suitable if field-measured infiltration rates exceed 0.3 inches per hour.

Figure 11-S12-1 Examples of Underground Infiltration Systems

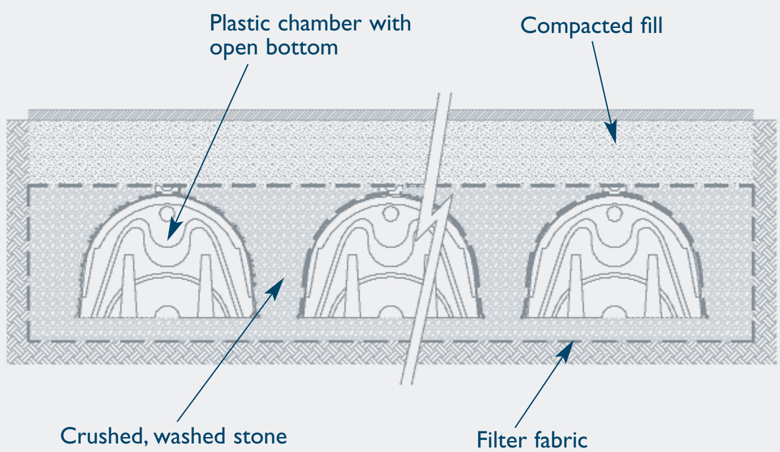
Modular Underground Infiltration System





Elevation

Underground Plastic Chamber System



Elevation

Source: Invisible Structures, Inc. and CULTEC, Inc.

Alum Injection

Source: Photo courtesy of Adell Donaghue.

Treatment Practice Type

Primary Treatment Practice	
Secondary Treatment Practice	●

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Partial Benefit
Phosphorus	Partial Benefit
Nitrogen	Partial Benefit
Metals	Partial Benefit
Pathogens	Low or Unknown Benefit
Floatables	Low or Unknown Benefit
Oil and Grease	Low or Unknown Benefit
Dissolved Pollutants	Partial Benefit
Runoff Volume Reduction	
Runoff Capture	Significant Benefit
Groundwater Recharge	Significant Benefit
Stream Channel Protection	Significant Benefit
Peak Flow Control	Significant Benefit

Key: ■ Significant Benefit
■ Partial Benefit
□ Low or Unknown Benefit

Suitable Applications

Pretreatment	Significant Benefit
Treatment Train	Significant Benefit
Ultra-Urban	Significant Benefit
Stormwater Retrofits	Significant Benefit
Other	Significant Benefit

Description

Alum injection is the addition of aluminum sulfate (alum) solution to stormwater before discharging to a receiving water body or stormwater treatment practice. When alum is injected into stormwater it binds with suspended solids, metals, and phosphorus and forms aluminum phosphate and aluminum hydroxide precipitates. These precipitates settle out of the water column and are deposited in the bottom sediments in a stable, inactive state (referred to as "floc").

The injection of liquid alum into storm sewers has been used to reduce the water quality impacts of stormwater runoff to lakes and other receiving water bodies, particularly to reduce high phosphorus levels and address eutrophic conditions (EPA, 2002). Alum injection systems are commonly used in some parts of the country as stormwater retrofits for existing discharges to lakes and ponds, but may also be used as pretreatment for stormwater ponds and other treatment practices (ASCE, 2001). Alum addition should be considered only after all other best management practices have been implemented.

Reasons for Limited Use

- *Limited long-term performance data.*
- *Requires ongoing operation unlike most other stormwater treatment practices.*
- *Improper dosing of chemicals may have negative impacts on downstream water bodies.*
- *Increases the volume of sediment/floc (and associated pollutant concentrations) that must be disposed of.*
- *Typically not cost effective for drainage areas less than 50 acres.*
- *Alum application may be approved as part of a state stormwater permit or could require an individual state permit. The DEP Water Management Bureau should be contacted for further permit guidance.*

Suitable Applications

- *Best suited to situations where a large volume of water is stored in one area.*
- *As part of a stormwater treatment train or pretreatment step to further reduce turbidity and fine suspended solids.*
- *For existing stormwater discharges to existing ponds and lakes, particularly in highly developed areas, where new stormwater treatment practices or other treatment options are not feasible.*

Design Considerations

Design: Alum injection systems typically consist of a flow-weighted dosing system designed to fit inside a storm sewer manhole, remotely located alum storage tanks, and a downstream pond or treatment practice that allows alum and pollutants to settle out (EPA, 2002). Alum dosage rates generally range between 5 and 10 milligrams per liter of alum solution and are determined on a flow-weighted basis during storm events. Lime is often added to raise the pH (between 8 and 11) and enhance pollutant settling. Jar testing is recommended to determine alum dosing rates and the need for pH control. Injection points in the storm drainage system should be approximately 100 feet upstream of the discharge point (ASCE, 2001). In addition to the settling pond, a separate floc collection pump-out facility is recommended to reduce the chance of resuspension and transport of floc to receiving waters by pumping floc to the sanitary sewer or onto nearby upland areas (with appropriate local, state, and federal regulatory approval, as necessary).

Operation and Maintenance: Typical operation and maintenance requirements for alum injection systems include maintenance of pump equipment, power, chemical replacement, routine inspections, and equipment replacement (doser and pump-out facility). A trained operator should be on-site to adjust the chemical dosage and regulate flows, if necessary. Alum injection systems also require continued monitoring of water quality to detect potential negative impacts to receiving waters. The settling basin or pond should be dredged periodically to dispose of accumulated floc.

Cost Considerations: Alum injection is a relatively expensive and labor-intensive treatment practice. Construction costs depend on watershed size and the number of outfalls treated, but construction costs generally range from $135,000 to $400,000. Due to the high construction cost, alum injection is not cost effective for drainage areas less than 50 acres. Operation and maintenance costs can vary from $6,500 to $50,000 per year depending on the size of the system (Harper and Herr, 1996).

References

American Society of Civil Engineers (ASCE). 2001. *A Guide for Best Management Practice (BMP) Selection in Urban Developed Areas*. Urban Water Infrastructure Management Committee's Task Committee for Evaluating Best Management Practices. Reston, Virginia.

Harper, H.H. and J.L. Herr. 1996. *Alum Treatment of Stormwater Runoff: The First Ten Years*. Environmental Research and Design. Orlando, Florida.

United States Environmental Protection Agency (EPA). 2002. *National Menu of Best Management Practices for Stormwater Phase II*. URL: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/post_3.cfm, Last Modified August 15, 2002.

Appendix A
Plant List

Appendix A: Plant List

1. Salt-Tolerant Plants

These plant species are suitable for planting within 80 feet of a roadside that is subject to de-icing and anti-icing application of salts.

Trees

White Oak *(Quercus alba)*
Red Oak *(Quercus rubra)*
White Poplar *(Populus alba)*
Blue Spruce *(Picea pungens)*
Green Ash *(Fraxinus pennsylvanica)*
Eastern Cottonwood *(Populus deltoides)*
Eastern White Pine *(Pinus strobus)*
Hawthorn *(Crataegus spp.)*
Pitch Pine *(Pinus rigida)*
Honeylocust *(Gleditsia triacanthos)*

Shrubs

Forsythia *(Forsythia x intermedia)*
Buttonbush *(Cephalanthus occidentalis)*
Bayberry *(Myrica pennsylvanica)*
Black Chokeberry *(Aronia melanocarpa)*
Red Chokeberry *(Aronia arbutifolia)*
Marsh Elder or High Tide Bush *(Iva frutescens)*
Groundsel *(Baccharis halimifolia)*

Grasses/Herbs

Birdsfoot trefoil *(Lotus corniculatus)*
Perennial ryegrass *(Lolium perenne)*
Switchgrass *(Panicum virgatum)*
Tall Fescue *(Festuca arundinacea)*
Alfalfa *(Medicago sativa)*
Cattails *(Typha domingensis)*

2. Native Plants/Xeriscaping

These plant species are native or adapted to southern New England. Information on these species and others that may be suitable for xeriscaping may be found in the references at the end of this appendix, including the Connecticut Native Tree and Shrub Availability List (DEP).

Trees

Eastern Red Cedar *(Juniperus virginiana)*
Flowering Dogwood *(Cornus florida)*
Hackberry *(Celtis occidentalis)*
Hawthorn *(Crataegus spp.)*
Hickories *(Carya spp.)*
Oaks *(Quercus spp.)*
Walnuts *(Juglans spp.)*
Atlantic White Cedar *(Chamaecyparis thyoides)*
Black Spruce *(Picea mariana)*
White Pine *(Pinus strobus)*
Black Cherry *(Prunus serotina)*
Choke Cherry *(Prunus virginiana)*

Shrubs
For Dry, Sunny Areas

Bayberry *(Myrica pensylvanica)*
Lowbush Blueberry *(Vaccinium augustifolium)*
Ground Juniper *(Juniperus communis)*
New Jersey Tea *(Ceanothus americanus)*
Sweet Fern *(Comptonia peregrina)*

For Shaded Areas

Hazelnut *(Corylus americana, C. cornuta)*
Mountain Laurel *(Kalmia latifolia)*
Swamp Azalea *(Rhododendron viscosum)*
Viburnums *(V. acerfolium, V. cassinoides, V. alnifolium)*

For Moist Sites

Dogwoods *(Cornus spp.)*
Elderberry *(Sambucus canadensis)*
Highbush Blueberry *(Vaccinium corymbosum)*
Pussy Willow *(Salix discolor)*
Shadbush Serviceberry *(Amelanchier canadensis)*
Spicebush *(Lindera benzoin)*
Spirea *(Spirea latifolia)*
Swamp azalea *(Rhododendron viscosum)*
Sweet Pepperbush *(Clethra alnifolia)*
Viburnums *(Viburnum spp.)*
Winterberry *(Ilex verticillata)*
Witch Hazel *(Hamamelis virginiana)*

Perennials

Wild red columbine *(Aquilegia canadensis)*
Bearberry, kinnickinick *(Arctostaphylos uva-ursi)*
Wild ginger *(Asarum canadense)*
Butterfly weed *(Asclepias tuberosa)*
White wood aster *(Aster divaricatus)*
New England aster *(Aster novae-angliae)*
Marsh marigold *(Caltha palustris)*
Wild geranium *(Geranium maculatum)*
Cardinal flower *(Lobelia cardinalis)*
Solomon's plume *(Maianthemum racemosum, syn. Smilacina racemosa)*
Partridgeberry *(Mitchella repens)*
Wild blue phlox *(Phlox divaricata)*
Bloodroot *(Sanguinaria canadensis)*
Foamflower *(Tiarella cordifolia)*

Grasses

Big bluestem *(Andropogon gerardii)*
Switchgrass *(Panicum virgatum)*
Little bluestem *(Schizachyrium scoparium, syn. Andropogon scoparius)*

3. Stormwater Ponds and Wetlands Plant List

This section contains planting guidance for stormwater ponds and wetlands. The following lists emphasize the use of plants native to Connecticut and southern New England and are intended as general guidance for planning purposes. Local landscape architects and nurseries may provide additional information, including plant availability, for specific applications.

Plantings for stormwater ponds and wetlands should be selected to be compatible with the various hydrologic zones within these treatment practices (NYDEC, 2001). The hydrologic zones reflect the degree and duration of inundation by water. Plants recommended for a particular zone can generally tolerate the hydrologic conditions that typically exist within that zone. **Table A-1** summarizes recommended plantings (trees/shrubs and herbaceous plants) within each hydrologic zone. This list is not intended to be exhaustive, but includes a number of recommended native species that are generally available from commercial nurseries. Other plant species may be acceptable if they can be shown to be appropriate for the intended hydrologic zone.

Table A-1 Plant List for Stormwater Ponds and Wetlands

Hydrologic Zone	Zone Description	Plant Name and Form	
Zone 1 Deep Water Pool	❍ 1 to 6 feet deep, permanent pool ❍ Submergent plants (if any at all) ❍ Not routinely planted due to limited availability of plants that can survive in this zone and potential clogging of outlet structure ❍ Plants reduce resuspension of sediments and improve oxidation/aquatic habitat	***Trees and Shrubs*** Not recommended ***Herbaceous Plants*** Coontail *(Ceratophyllumdemersum)* Duckweed *(Lemma sp.)* Pond Weed, Sago *(Potamogeton Pectinatus)* Waterweed *(Elodea canadensis)* Wild Celery *(Valisneria Americana)*	 Submergent Submergent/Emergent Submergent Submergent Submergent
Zone 2 Shallow Water Bench	❍ 1 foot below the normal pool (aquatic bench in stormwater ponds) ❍ Plants partially submerged ❍ Emergent wetland plants ❍ Plants reduce resuspension of sediments, enhance pollutant removal, and provide aquatic and nonaquatic habitat	***Trees and Shrubs*** Buttonbush *(Cepahlanthus occidentalis)* ***Herbaceous Plants*** Arrow arum *(Peltandra virginica)* Arrowhead, Duck Potato *(Saggitaria latifolia)* Blue Flag Iris *(Iris versicolor)* Blue Joint *(Calamagrotis canadensis)* Broomsedge *(Andropogon virginicus)* Bushy Beardgrass *(Andropogon glomeratus)* Cattail *(Typha sp.)* Common Three-Square *(Scirpus pungens)* Duckweed *(Lemma sp.)* Giant Burreed *(Sparganium eurycarpum)* Long-leaved Pond Weed *(Potamogeton nodosus)* Marsh Hibiscus *(Hibiscus moscheutos)* Pickerelweed *(Pontederia cordata)* Rice Cutgrass *(Leersia oryzoides)* Sedges *(Carex spp.)* Soft-stem Bulrush *(Scirpus validus)* Smartweed *(Polygonum spp)* Soft Rush *(Juncus effusus)* Spatterdock *(Nuphar luteum)* Switchgrass *(Panicum virgatum)* Sweet Flag *(Acorus calamus)* Wild Rice *(Zizania aquatica)* Wool Grass *(Scirpus cyperinus)*	 Deciduous shrub Emergent Emergent Emergent Emergent Perimeter Emergent Emergent Emergent Submergent/Emergent Emergent Rooted Submerged Aquatic Emergent Emergent Emergent Emergent Emergent Emergent Emergent Emergent Perimeter Herbaceous Emergent Emergent

Table A-1 Plant List for Stormwater Ponds and Wetlands *(continued)*

Hydrologic Zone	Zone Description	Plant Name and Form	
Zone 3 Shoreline Fringe	❍ 1 foot above the normal pool (includes safety bench of pond) ❍ Frequently inundated if storm events are subject to extended detention ❍ Plants must be able to withstand inundation during storms and occasional drought ❍ Plants provide shoreline stabilization, shade the shoreline, enhance pollutant removal, and provide wildlife habitat (or selected to control over-population of waterfowl)	***Trees and Shrubs***	
		Arrowwood Viburrium *(Viburrium dentatum)*	Deciduous shrub
		Black Ash *(Fraxinus nigra)*	Deciduous tree
		Black Willow *(Salix nigra)*	Deciduous tree
		Buttonbush *(Cepahlanthus occidentalis)*	Deciduous shrub
		Common Spice Bush *(Lindera benzoin)*	Deciduous shrub
		Elderberry *(Sambucus canadensis)*	Deciduous shrub
		Larch, Tamarack *(Larix latricina)*	Coniferous tree
		Pin Oak *(Quercus palustris)*	Deciduous tree
		Red Maple *(Acer rubrum)*	Deciduous tree
		River Birch *(Betula nigra)*	Deciduous tree
		Silky Dogwood *(Cornus amomum)*	Deciduous shrub
		Slippery Elm *(Ulnus rubra)*	Deciduous tree
		Smooth Alder *(Alnus serrulata)*	Deciduous tree
		Speckled Alder *(Alnus rugosa)*	Deciduous shrub
		Swamp White Oak (Quercus bicolor)	Deciduous tree
		Swamp Rose (Rosa Palustrus)	Deciduous shrub
		Tupelo *(Nyssa sylvatica vari biflora)*	Deciduous tree
		Winterberry *(Ilex verticillata)*	Deciduous shrub
		Herbaceous Plants	
		Arrow arum *(Peltandra virginica)*	Emergent
		Arrowhead, Duck Potato *(Saggitaria latifolia)*	Emergent
		Blue Flag Iris *(Iris versicolor)*	Emergent
		Blue Joint *(Calamagrotis canadensis)*	Emergent
		Blue Vervain *(Verbena hastata)*	Emergent
		Boneset *(Eupatorium perfoliatum)*	Emergent
		Broomsedge *(Andropogon virginicus)*	Perimeter
		Bushy Beardgrass *(Andropogon glomeratus)*	Emergent
		Cattail *(Typha sp.)*	Emergent
		Chufa *(Cyperus esculentus)*	Emergent
		Creeping Bentgrass *(Agrostis stolonifera)*	Emergent
		Creeping Red Fescue *(Festuca rubra)*	Emergent
		Flat-top Aster *(Aster umbellatus)*	Emergent
		Fowl Bluegrass *(Poa palustris)*	Emergent
		Giant Burreed *(Sparganium eurycarpum)*	Emergent
		Green Bulrush *(Scirpus atrovirens)*	Emergent
		Marsh Hibiscus *(Hibiscus moscheutos)*	Emergent
		Pickerelweed *(Pontederia cordata)*	Emergent
		Redtop *(Agrostis alba)*	Perimeter
		Rice Cutgrass *(Leersia oryzoides)*	Emergent
		Sedges *(Carex spp)*	Emergent
		Soft-stem Bulrush *(Scirpus validus)*	Emergent
		Smartweed *(Polygonum spp.)*	Emergent
		Soft Rush *(Juncus effusus)*	Emergent
		Spotted Joe-pye weed *(Eupatorium maculatum)*	Emergent
		Swamp Aster *(Aster puniceus)*	Emergent
		Switchgrass *(Panicum virgatum)*	Perimeter
		Sweet Flag *(Acorus calamus)*	Herbaceous
		Water Plantain *(Alisma plantago-aquatica)*	Emergent
		Wild-rye *(Elymus spp.)*	Emergent
		Wool Grass *(Scirpus cyperinus)*	Emergent

Table A-1 Plant List for Stormwater Ponds and Wetlands *(continued)*

Hydrologic Zone	Zone Description	Plant Name and Form	
Zone 4 Riparian Fringe	❍ 1 to 4 feet above the normal pool ❍ Includes nearly all of temporary extended detention volume ❍ Periodically inundated after storms ❍ Plants must be able to withstand inundation during storms and occasional drought ❍ Plants provide shoreline stabilization, shade the shoreline, enhance pollutant removal, and provide wildlife habitat (or selected to control over-population of waterfowl)	***Trees and Shrubs***	
		American Elm *(Ulmus americana)*	Deciduous tree
		Arrowwood Viburium *(Viburium dentatum)*	Deciduous shrub
		Bayberry *(Myrica pensylvanica)*	Deciduous shrub
		Black Ash *(Fraxinus nigra)*	Deciduous tree
		Blackgum or Sourgum *(Nyssa sylvatica)*	Deciduous tree
		Black Willow *(Salix nigra)*	Deciduous tree
		Buttonbush *(Cepahlanthus occidentalis)*	Deciduous shrub
		Common Spice Bush *(Lindera benzoin)*	Deciduous shrub
		Eastern Cottonwood *(Populus deltoides)*	Deciduous tree
		Eastern Red Cedar *(Juniperus virginiana)*	Coniferous tree
		Elderberry *(Sambucus canadensis)*	Deciduous shrub
		Green Ash, Red Ash *(Fraxinus pennsylvania)*	Deciduous tree
		Larch, Tamarack *(Larix latricina)*	Coniferous tree
		Pin Oak *(Quercus palustris)*	Deciduous tree
		Red Maple *(Acer rubrum)*	Deciduous tree
		River Birch *(Betula nigra)*	Deciduous tree
		Shadowbush, Serviceberry *(Amelanchier*	Deciduous shrub
		Canadensis)	Deciduous shrub
		Silky Dogwood *(Cornus amomum)*	Deciduous tree
		Slippery Elm *(Ulnus rubra)*	Deciduous tree
		Smooth Alder *(Alnus serrulata)*	Deciduous shrub
		Speckled Alder *(Alnus rugosa)*	Deciduous tree
		Swamp White Oak *(Quercus bicolor)*	Deciduous shrub
		Swamp Rose *(Rosa Palustrus)*	Deciduous tree
		Sycamore *(Platanus occidentalis)*	Deciduous tree
		Tulip Tree *(Liriodendron tulipifera)*	Deciduous tree
		Tupelo *(Nyssa sylvatica)*	Deciduous tree
		Winterberry *(Ilex verticillata)*	Deciduous shrub
		Witch Hazel *(Hamamelis virginiana)*	Deciduous shrub
		Herbaceous Plants	
		Big Bluestem *(Andropogon gerardi)*	Perimeter
		Birdfoot deervetch *(Lotus Corniculatus)*	Perimeter
		Blue Vervain *(Verbena hastata)*	Emergent
		Boneset *(Eupatorium perfoliatum)*	Emergent
		Blue Joint *(Calamagrotis canadensis)*	Emergent
		Cardinal flower *(Lobelia cardinalis)*	Perimeter
		Chufa *(Cyperus esculentus)*	Emergent
		Fowl Bluegrass *(Poa palustris)*	Emergent
		Fowl mannagrass *(Glyceria striata)*	Perimeter
		Green Bulrush *(Scirpus atrovirens)*	Emergent
		Redtop *(Agrostis alba)*	Perimeter
		Sedges *(Carex spp)*	Emergent
		Smartweed *(Polygonum spp.)*	Emergent
		Soft Rush *(Juncus effusus)*	Emergent
		Spotted Joe-pye weed *(Eupatorium maculatum)*	Emergent
		Swamp Aster *(Aster puniceus)*	Emergent
		Switchgrass *(Panicum virgatum)*	Perimeter
		Water Plantain *(Alisma plantago-aquatica)*	Emergent
		Wild-rye *(Elymus spp.)*	Emergent
		Wild-rye *(Elymus spp.)*	Emergent

Table A-1 Plant List for Stormwater Ponds and Wetlands *(continued)*

Hydrologic Zone	Zone Description	Plant Name and Form	
Zone 5 Floodplain Terrace	❍ Extends from the maximum channel protection water surface elevation (typically 2-yr storm) to the 100-year water surface elevation ❍ Infrequently inundated ❍ Plants must be able to withstand occasional, brief inundation and occasional drought conditions ❍ Plants provide slope stabilization, shade, and wildlife habitat	***Trees and Shrubs***	
		American Elm *(Ulmus americana)*	Deciduous tree
		Bayberry *(Myrica pensylvanica)*	Deciduous shrub
		Black Ash *(Fraxinus nigra)*	Deciduous tree
		Black Cherry *(Prunus serotina)*	Deciduous tree
		Blackgum or Sourgum *(Nyssa sylvatica)*	Deciduous tree
		Black Willow *(Salix nigra)*	Deciduous tree
		Buttonbush *(Cepahlanthus occidentalis)*	Deciduous shrub
		Common Spice Bush *(Lindera benzoin)*	Deciduous shrub
		Eastern Cottonwood *(Populus deltoides)*	Deciduous tree
		Eastern Red Cedar *(Juniperus virginiana)*	Coniferous tree
		Elderberry *(Sambucus canadensis)*	Deciduous shrub
		Green Ash, Red Ash *(Fraxinus pennsylvania)*	Deciduous tree
		Hackenberry *(Celtis occidentalis)*	Deciduous tree
		Pin Oak *(Quercus palustris)*	Deciduous tree
		Red Maple *(Acer rubrum)*	Deciduous tree
		River Birch *(Betula nigra)*	Deciduous tree
		Shadowbush, Serviceberry *(Amelanchier canadensis)*	Deciduous shrub
		Silky Dogwood *(Cornus amomum)*	Deciduous shrub
		Slippery Elm *(Ulnus rubra)*	Deciduous tree
		Smooth Alder *(Alnus serrulata)*	Deciduous tree
		Swamp White Oak *(Quercus bicolor)*	Deciduous tree
		Sweetgum *(Liquidambar styraciflua)*	Deciduous tree
		Sycamore *(Platanus occidentalis)*	Deciduous tree
		Tulip Tree *(Liriodendron tulipifera)*	Deciduous tree
		Tupelo *(Nyssa sylvatica)*	Deciduous tree
		White Ash *(Fraxinus americana)*	Deciduous tree
		Winterberry *(Ilex verticillata)*	Deciduous shrub
		Witch Hazel *(Hamamelis virginiana)*	Deciduous shrub
		Herbaceous Plants	
		Annual Ryegrass *(Lolium multiflorum)*	Perimeter
		Big Bluestem *(Andropogon gerardi)*	Perimeter
		Birdfoot deervetch *(Lotus Corniculatus)*	Perimeter
		Cardinal flower *(Lobelia cardinalis)*	Perimeter
		Creeping Red Fescue *(Festuca rubra)*	Perimeter
		Fowl mannagrass *(Glyceria striata)*	Perimeter
		Redtop *(Agrostis alba)*	Perimeter
		Timothy *(Phleum pratense)*	Perimeter
		White Clover *(Trifolium repens)*	Perimeter
		Switchgrass *(Panicum virgatum)*	Perimeter
Zone 6 Upland Slopes	❍ Above the maximum 100-year water surface elevation ❍ Typically includes outer buffer of pond or wetland ❍ Plants should be selected based on soil condition, light, and function (not inundation since almost never inundated)	***Trees and Shrubs***	
		American Elm *(Ulmus americana)*	Deciduous tree
		Bayberry *(Myrica pensylvanica)*	Deciduous shrub
		Black Cherry *(Prunus serotina)*	Deciduous tree
		Blackgum or Sourgum *(Nyssa sylvatica)*	Deciduous tree
		Eastern Red Cedar *(Juniperus virginiana)*	Coniferous tree
		Elderberry *(Sambucus canadensis)*	Deciduous shrub
		Hackenberry *(Celtis occidentalis)*	Deciduous tree

Table A-1 Plant List for Stormwater Ponds and Wetlands *(continued)*

Hydrologic Zone	Zone Description	Plant Name and Form	
		Pin Oak *(Quercus palustris)*	Deciduous tree
		Red Maple *(Acer rubrum)*	Deciduous tree
		Shadowbush, Serviceberry *(Amelanchier canadensis)*	Deciduous shrub
		Sweetgum *(Liquidambar styraciflua)*	Deciduous tree
		Sycamore *(Platanus occidentalis)*	Deciduous tree
		Tulip Tree *(Liriodendron tulipifera)*	Deciduous tree
		White Ash *(Fraxinus Americana)*	Deciduous tree
		Herbaceous Plants	
		Birdfoot deervetch *(Lotus Corniculatus)*	Perimeter
		Cardinal flower *(Lobelia cardinalis)*	Perimeter
		Switchgrass *(Panicum virgatum)*	Perimeter

Source: Adapted from NYDEC, 2001; New England Wetland Plants, Inc.

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Appendix B
Water Quality Flow (WQF) and Flow Diversion Guidance

Water Quality Flow Calculation

The water quality flow (WQF) is the peak flow rate associated with the water quality design storm. This section describes the recommended procedure for calculating the water quality flow (WQF) for the design of:

- *Grass drainage channels (not water quality swales, which should be designed based on water quality volume - WQV)*
- *Pre-manufactured stormwater treatment devices (e.g., hydrodynamic separators, catch basin inserts, and media filters)*
- *Flow diversion structures for off-line stormwater treatment practices*

The WQF should be calculated using the WQV described in Chapter Seven. This WQV, converted to watershed inches, should be substituted for the runoff depth (*Q*) in the Natural Resources Conservation Service (formerly Soil Conservation Service), TR-55 Graphical Peak Discharge Method. The procedure is based on the approach described in Claytor and Schueler, 1996.

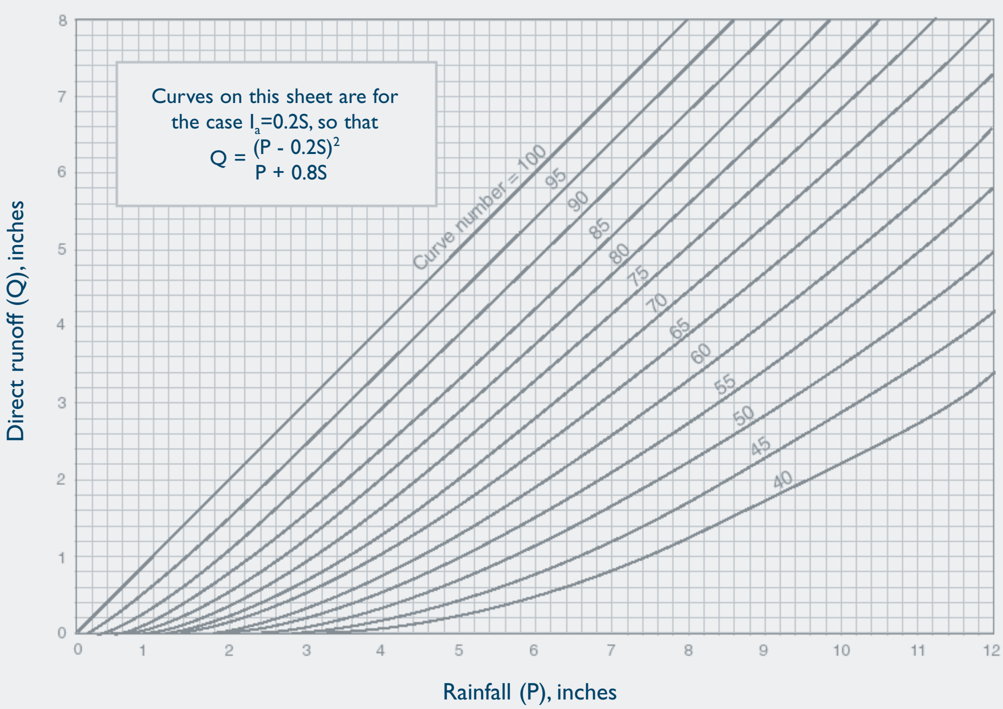
1. Compute the NRCS Runoff Curve Number (CN) using the following equation, or graphically using **Figure 2-1** from TR-55 (USDA, 1986) (reproduced below):

$$CN = \frac{1000}{\left[10 + 5P + 10Q - 10(Q^2 + 1.25QP)^{1/2}\right]}$$

where: CN = Runoff Curve Number
P = design precipitation, inches (1" for water quality storm)
Q = runoff depth (in watershed inches)

$$= \frac{[WQV\,(acre-feet)] \times [12(inches/foot)]}{Drainage\ Area\ (acres)}$$

Figure 2-1 Solution of Runoff Equation



2. Compute the time of concentration (t_c) based on the methods described in Chapter 3 of TR-55. A minimum value of 0.167 hours (10 minutes) should be used. For sheet flow, the flow path should not be longer than 300 feet.

3. Using the computed CN, t_c, and drainage area (A) in acres, compute the peak discharge for the water quality storm (i.e., the water quality flow [WQF]), based on the procedures described in Chapter 4 of TR-55.

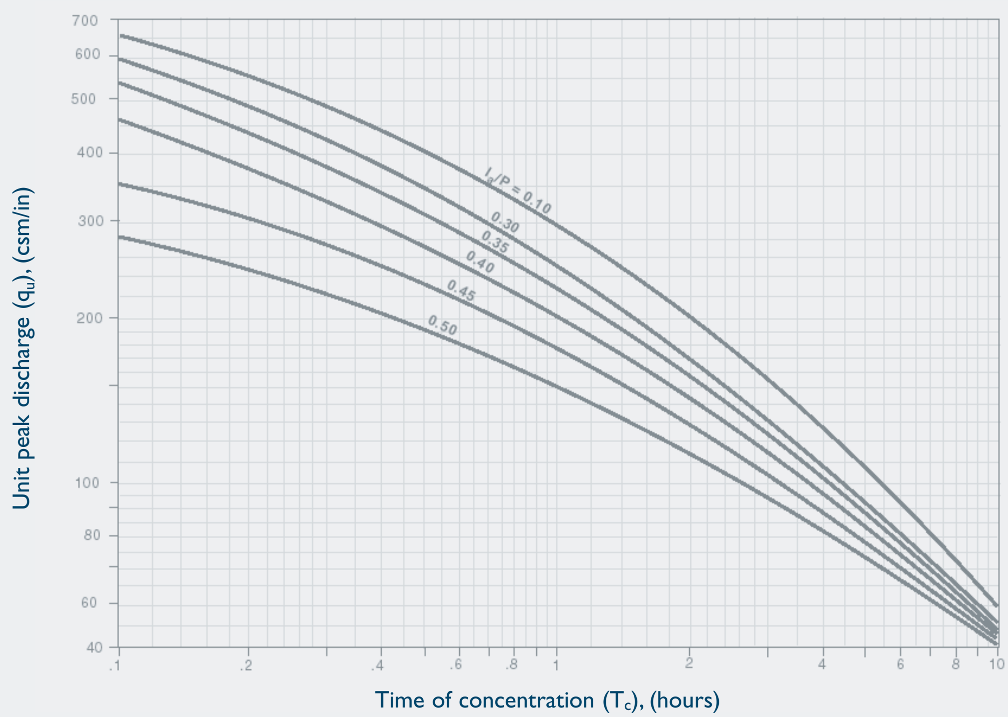
   ❍ *Read initial abstraction (I_a) from Table 4-1 in Chapter 4 of TR-55 (reproduced below); compute I_a/P*

Table 4-1 I_a values for runoff curve numbers

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

   ❍ *Read the unit peak discharge (q_u) from Exhibit 4-III in Chapter 4 of TR-55 (reproduced below) for appropriate t_c*

Exhibit 4-111 Unit peak discharge (q_u) for NRCS (SCS) type III rainfall distribution



- *Substituting the water quality volume (WQV), converted to watershed inches, for runoff depth (Q), compute the water quality flow (WQF) from the following equation:*

$$WQF = (q_u)(A)(Q)$$

where: WQV = water quality flow (cfs)
q_u = unit peak discharge (cfs/mi2/inch)
A = drainage area (mi2)
Q = runoff depth (in watershed inches)

$$= \frac{[WQV\,(acre - feet)] \text{x} [12(inches/foot)]}{Drainage\ Area\ (acres)}$$

Other peak flow calculation methods may be used for determining the WQF, such as those recommended by manufacturers of proprietary treatment systems, provided that the WQF calculated by other methods is equal to or greater than the WQF calculated using the above NRCS Graphical Peak Discharge Method.

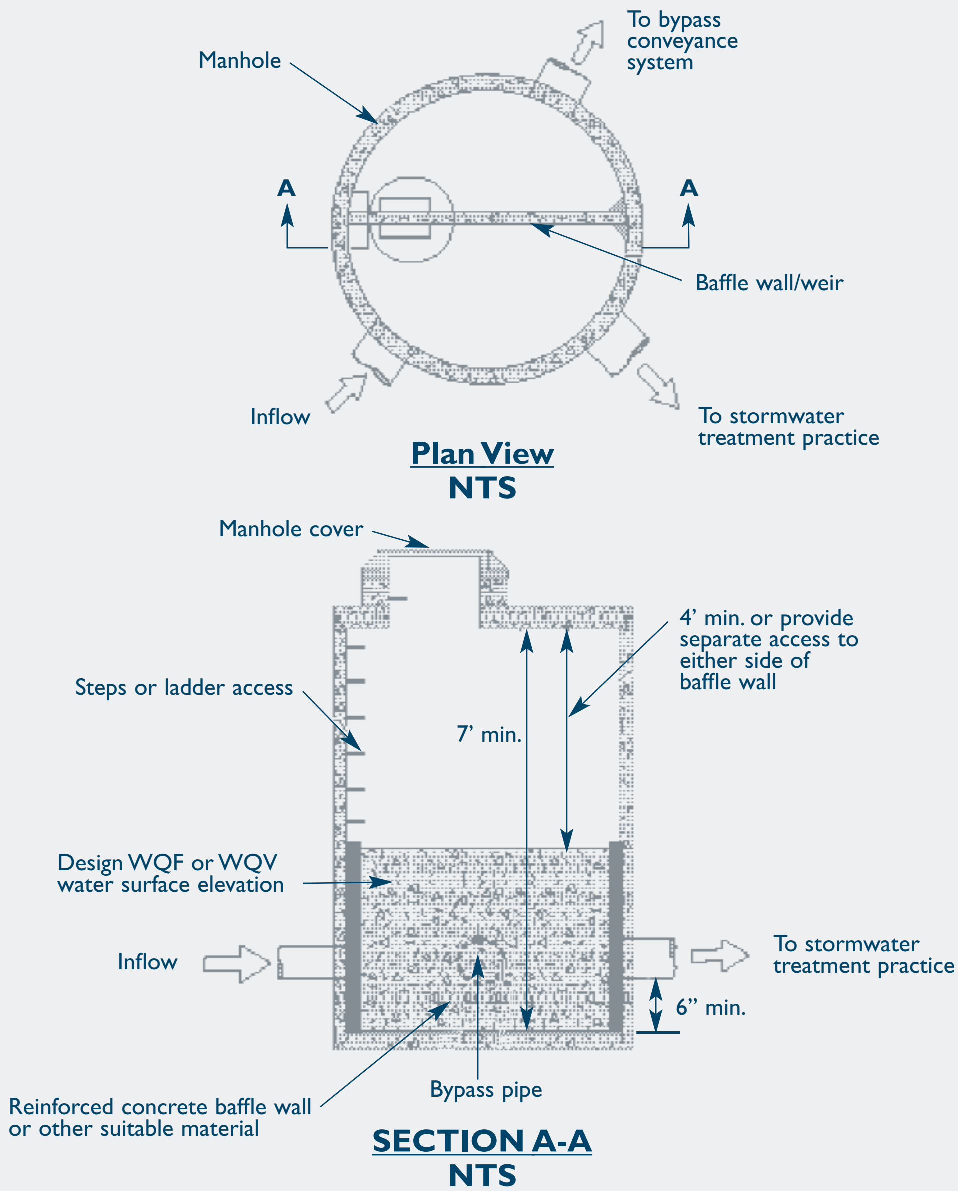
Flow Diversion Structures

Flow diversion structures, also called flow splitters, are designed to deliver flows up to the design water quality flow (WQF) or water quality volume (WQV) to off-line stormwater treatment practices. Flows in excess of the WQF or WQV are diverted around the treatment facility with minimal increase in head at the flow diversion structure to avoid surcharging the treatment facility under higher flow conditions. Flow diversion structures are typically manholes or vaults equipped with weirs, orifices, or pipes to bypass excess runoff. A number of design options exist. **Figures B-1** through **B-3** show common examples of flow diversion structures for use upstream of stormwater treatment practices. Other equivalent designs that achieve the result of diverting flows in excess of the WQF or WQV around the treatment facility, including bypasses or overflows located inside the facility, are also acceptable.

The following general procedures are recommended for design of flow diversion structures:

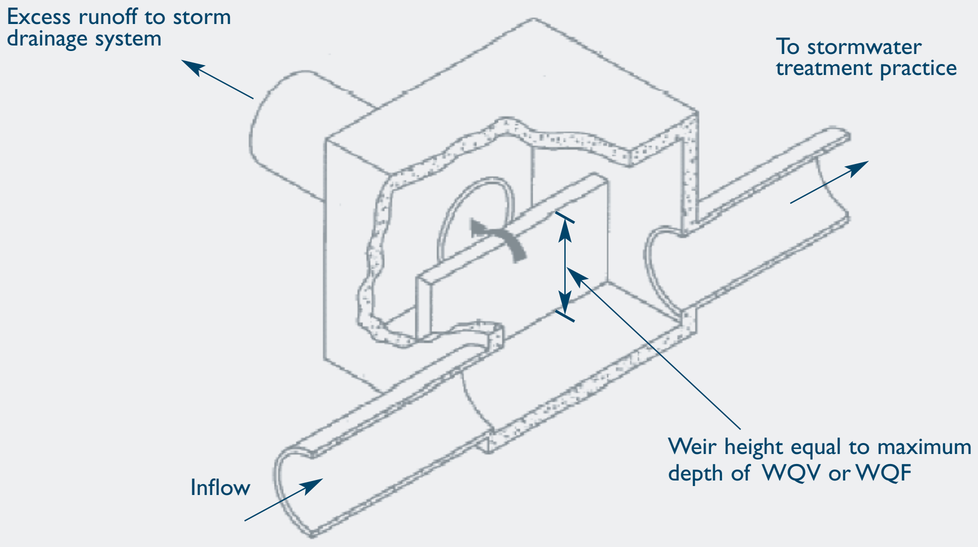
- *Locate the top of the weir or overflow structure at the maximum water surface elevation associated with the WQF, or the water surface elevation in the treatment practice when the entire WQV is being held, whichever is higher.*
- *Determine the diversion structure dimensions required to divert flows in excess of the WQF using standard equations for a rectangular sharp-crested weir, uniform flow in pipes or channels, or orifice depending on the type of diversion structure.*
- *Provide sufficient freeboard in the stormwater treatment practice and flow splitter to accommodate flow over the diversion structure.*
- *Limit the maximum head over the flow diversion structure to avoid surcharging the stormwater treatment practice under high flow conditions. Flow to the stormwater treatment practice at the 100-year water surface elevation should not increase the WQF by more than 10 percent.*
- *Design diversion structures to withstand the effects of freezing, frost in foundations, erosion, and flotation due to high water conditions. These structures should be designed to minimize clogging potential and to allow for ease of inspection and maintenance.*

Figure B-1 Flow Diversion Structure Design Option 1



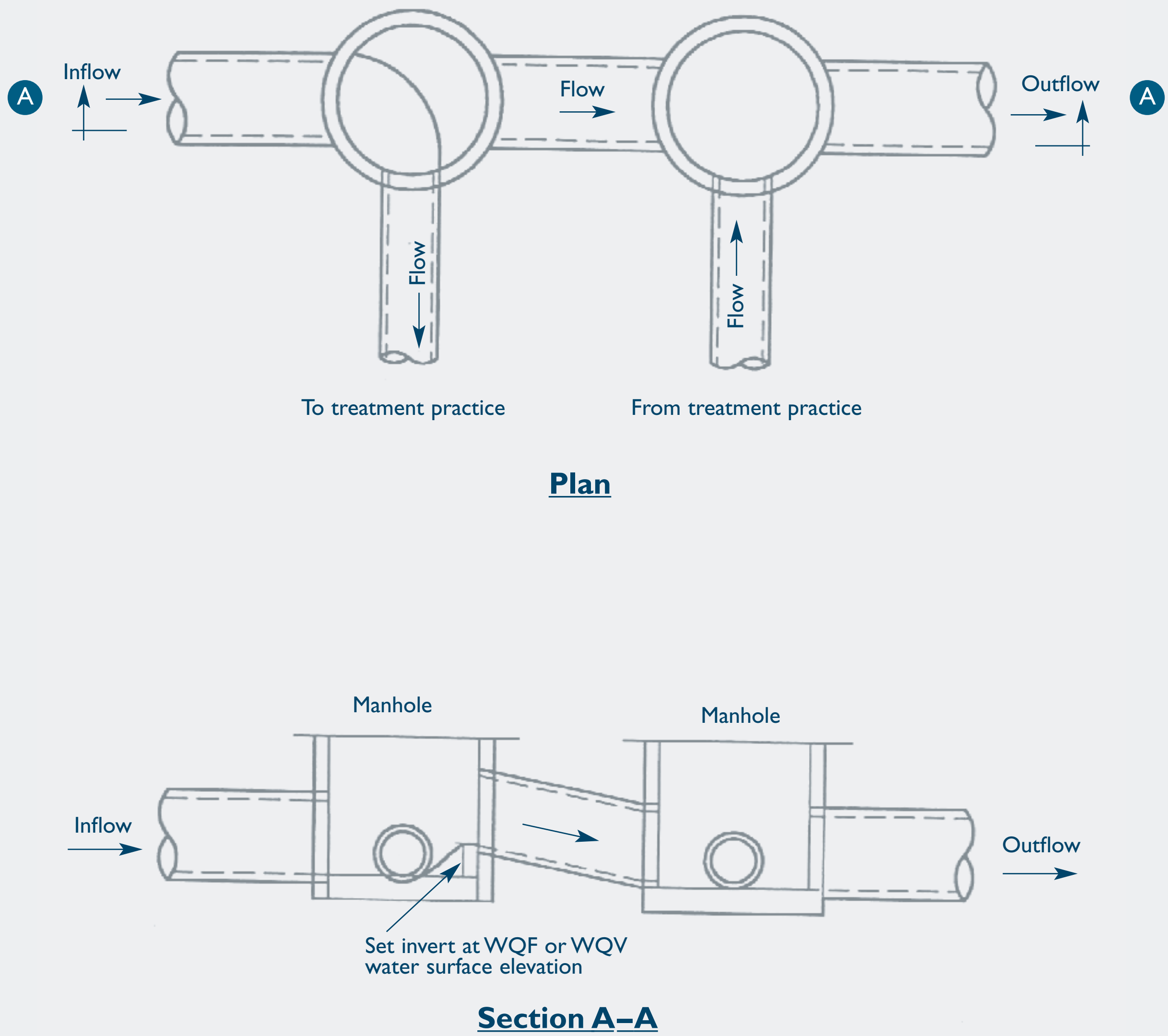
Source: Adapted from Washington, 2000.

Figure B-2 Flow Diversion Structure Design Option 2



Source: Adapted from City of Sacramento, 2000.

Figure B-3 Flow Diversion Structure Design Option 3



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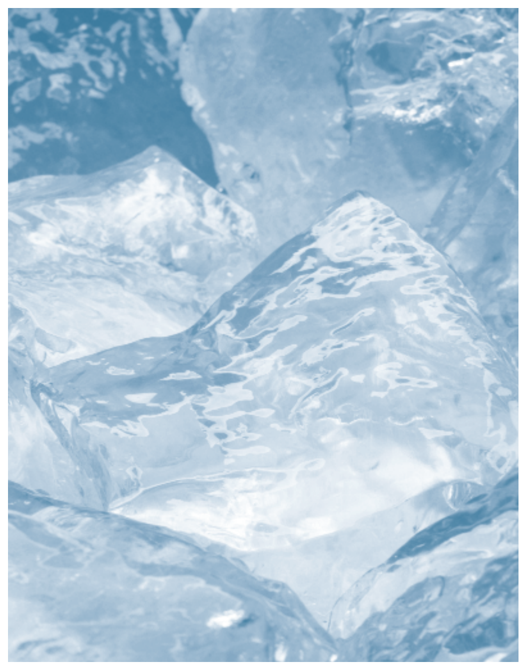
Appendix C
Model Ordinances



This Appendix contains model ordinances for:

- *Illicit Discharge Detection and Elimination (USEPA, 2002)*
- *Stormwater Operation and Maintenance (CWP, 2002)*

A model ordinance that was developed for protection of Long Island Sound is included, as well as examples of specific ordinances or sections of ordinances that have been adopted by various Connecticut municipalities. These model ordinances and examples are not exhaustive and are not necessarily appropriate for adoption in their entirety without modification.

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Model Illicit Discharge and Connection Stormwater Ordinance[1]

ORDINANCE NO. ______

Section 1. Purpose/Intent.

The purpose of this ordinance is to provide for the health, safety, and general welfare of the citizens of (______________________) through the regulation of non-storm water discharges to the storm drainage system to the maximum extent practicable as required by federal and state law. This ordinance establishes methods for controlling the introduction of pollutants into the municipal separate storm sewer system (MS4) in order to comply with requirements of the National Pollutant Discharge Elimination System (NPDES) permit process. The objectives of this ordinance are:

(1) To regulate the contribution of pollutants to the municipal separate storm sewer system (MS4) by stormwater discharges by any user

(2) To prohibit Illicit Connections and Discharges to the municipal separate storm sewer system

(3) To establish legal authority to carry out all inspection, surveillance and monitoring procedures necessary to ensure compliance with this ordinance

Section 2. Definitions.

For the purposes of this ordinance, the following shall mean:

Authorized Enforcement Agency: employees or designees of the director of the municipal agency designated to enforce this ordinance.

Best Management Practices (BMPs): schedules of activities, prohibitions of practices, general good house keeping practices, pollution prevention and educational practices, maintenance procedures, and other management practices to prevent or reduce the discharge of pollutants directly or indirectly to stormwater, receiving waters, or stormwater conveyance systems. BMPs also include treatment practices, operating procedures, and practices to control site runoff, spillage or leaks, sludge or water disposal, or drainage from raw materials storage.

Clean Water Act. The federal Water Pollution Control Act (33 U.S.C. § 1251 et seq.), and any subsequent amendments thereto.

Construction Activity. Activities subject to NPDES Construction Permits. Currently these include construction projects resulting in land disturbance of 1 acre or more. Such activities include but are not limited to clearing and grubbing, grading, excavating, and demolition.

Hazardous Materials. Any material, including any substance, waste, or combination thereof, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may cause, or significantly contribute to, a substantial present or potential hazard to human health, safety, property, or the environment when improperly treated, stored, transported, disposed of, or otherwise managed.

Illegal Discharge. Any direct or indirect non-storm water discharge to the storm drain system, except as exempted in Section X of this ordinance.

Illicit Connections. An illicit connection is defined as either of the following:

Any drain or conveyance, whether on the surface or subsurface, which allows an illegal discharge to enter the storm drain system including but not limited to any conveyances which allow any non-storm water discharge including sewage, process wastewater, and wash water to enter the storm drain system and any connections to the storm drain system from indoor drains and sinks, regardless of whether said drain or connection had been previously allowed, permitted, or approved by an authorized enforcement agency or, Any drain or conveyance connected from a commercial or industrial land use to the storm drain system which has not been documented in plans, maps, or equivalent records and approved by an authorized enforcement agency.

Industrial Activity. Activities subject to NPDES Industrial Permits as defined in 40 CFR, Section 122.26 (b)(14).

National Pollutant Discharge Elimination System (NPDES) Storm Water Discharge Permit. means a permit issued by EPA (or by a State under authority delegated pursuant to 33 USC § 1342(b)) that authorizes the discharge of pollutants to waters of the United States, whether the permit is applicable on an individual, group, or general areawide basis.

Non-Storm Water Discharge. Any discharge to the storm drain system that is not composed entirely of storm water.

Person. means any individual, association, organization, partnership, firm, corporation or other entity recognized by law and acting as either the owner or as the owner's agent.

Pollutant. Anything which causes or contributes to pollution. Pollutants may include, but are not limited to: paints, varnishes, and solvents; oil and other automotive fluids; non-hazardous liquid and solid wastes and yard wastes; refuse, rubbish, garbage, litter, or other discarded or abandoned objects, ordinances, and accumulations, so that same may cause or contribute to pollution; floatables; pesticides, herbicides, and fertilizers; hazardous substances and wastes; sewage, fecal coliform and pathogens; dissolved and particulate metals; animal wastes; wastes and residues that result from constructing a building or structure; and noxious or offensive matter of any kind.

Premises. Any building, lot, parcel of land, or portion of land whether improved or unimproved including adjacent sidewalks and parking strips.

Storm Drainage System. Publicly-owned facilities by which storm water is collected and/or conveyed, including but not limited to any roads with drainage systems, municipal streets, gutters, curbs, inlets, piped storm drains, pumping facilities, retention and detention basins, natural and human-made or altered drainage channels, reservoirs, and other drainage structures.

Storm Water. Any surface flow, runoff, and drainage consisting entirely of water from any form of natural precipitation, and resulting from such precipitation.

Stormwater Pollution Prevention Plan. A document which describes the Best Management Practices and activities to be implemented by a person or business to identify sources of pollution or contamination at a site and the actions to eliminate or reduce pollutant discharges to Stormwater, Stormwater Conveyance Systems, and/or Receiving Waters to the Maximum Extent Practicable.

Wastewater means any water or other liquid, other than uncontaminated storm water, discharged from a facility.

Section 3. Applicability.

This ordinance shall apply to all water entering the storm drain system generated on any developed and undeveloped lands unless explicitly exempted by an authorized enforcement agency.

Section 4. Responsibility for Administration.

The ________________________ [authorized enforcement agency] shall administer, implement, and enforce the provisions of this ordinance. Any powers granted or duties imposed upon the authorized enforcement agency may be delegated in writing by the Director of the authorized enforcement agency to persons or entities acting in the beneficial interest of or in the employ of the agency.

Section 5. Severability.

The provisions of this ordinance are hereby declared to be severable. If any provision, clause, sentence, or paragraph of this Ordinance or the application thereof to any person, establishment, or circumstances shall be held invalid, such invalidity shall not affect the other provisions or application of this Ordinance.

Section 6. Ultimate Responsibility.

The standards set forth herein and promulgated pursuant to this ordinance are minimum standards; therefore this ordinance does not intend nor imply that compliance by any person will ensure that there will be no contamination, pollution, nor unauthorized discharge of pollutants.

Section 7. Discharge Prohibitions.

Prohibition of Illegal Discharges.

No person shall discharge or cause to be discharged into the municipal storm drain system or watercourses any materials, including but not limited to pollutants or waters containing any pollutants that cause or contribute to a violation of applicable water quality standards, other than storm water. The commencement, conduct or continuance of any illegal discharge to the storm drain system is prohibited except as described as follows:

(1) The following discharges are exempt from discharge prohibitions established by this ordinance: water line flushing or other potable water sources, landscape irrigation or lawn watering, diverted stream flows, rising ground water, ground water infiltration to storm drains, uncontaminated pumped ground water, foundation or footing drains (not including active groundwater dewatering systems), crawl space pumps, air conditioning condensation, springs, non-commercial washing of vehicles, natural riparian habitat or wetland flows, swimming pools (if dechlorinated – typically less than one PPM chlorine), fire fighting activities, and any other water source not containing Pollutants.

(2) Discharges specified in writing by the authorized enforcement agency as being necessary to protect public health and safety.

(3) Dye testing is an allowable discharge, but requires a verbal notification to the authorized enforcement agency prior to the time of the test.

(4) The prohibition shall not apply to any non-storm water discharge permitted under an NPDES permit, waiver, or waste discharge order issued to the discharger and administered under the authority of the Federal Environmental Protection Agency, provided that the discharger is in full compliance with all requirements of the permit, waiver, or order and other applicable laws and regulations, and provided that written approval

has been granted for any discharge to the storm drain system.

Prohibition of Illicit Connections.

(1) The construction, use, maintenance or continued existence of illicit connections to the storm drain system is prohibited.

(2) This prohibition expressly includes, without limitation, illicit connections made in the past, regardless of whether the connection was permissible under law or practices applicable or prevailing at the time of connection.

(3) A person is considered to be in violation of this ordinance if the person connects a line conveying sewage to the MS4, or allows such a connection to continue.

Section 8. Suspension of MS4 QAccess.

Suspension due to Illicit Discharges in Emergency Situations

The ________________ [authorized enforcement agency] may, without prior notice, suspend MS4 discharge access to a person when such suspension is necessary to stop an actual or threatened discharge which presents or may present imminent and substantial danger to the environment, or to the health or welfare of persons, or to the MS4 or Waters of the United States. If the violator fails to comply with a suspension order issued in an emergency, the authorized enforcement agency may take such steps as deemed necessary to prevent or minimize damage to the MS4 or Waters of the United States, or to minimize danger to persons.

Suspension due to the Detection of Illicit Discharge

Any person discharging to the MS4 in violation of this ordinance may have their MS4 access terminated if such termination would abate or reduce an illicit discharge. The authorized enforcement agency will notify a violator of the proposed termination of its MS4 access. The violator may petition the authorized enforcement agency for a reconsideration and hearing.

A person commits an offense if the person reinstates MS4 access to premises terminated pursuant to this Section, without the prior approval of the authorized enforcement agency.

Section 9. Industrial or Construction Activity Dischrges.

Any person subject to an industrial or construction activity NPDES storm water discharge permit shall comply with all provisions of such permit. Proof of compliance with said permit may be required in a form acceptable to the ________________ [authorized enforcement agency] prior to the allowing of discharges to the MS4.

Section 10. Monitoring of Damages.

1. Applicability.

   This section applies to all facilities that have storm water discharges associated with industrial activity, including construction activity.

2. Access to Facilities.

(1) The ________________ [authorized enforcement agency] shall be permitted to enter and inspect facilities subject to regulation under this ordinance as often as may be necessary to determine compliance with this ordinance. If a discharger has security measures in force which require proper identification and clearance before entry into its premises, the discharger shall make the necessary arrangements to allow access to representatives of the authorized enforcement agency.

(2) Facility operators shall allow the ________________ [authorized enforcement agency] ready access to all parts of the premises for the purposes of inspection, sampling, examination and copying of records that must be kept under the conditions of an NPDES permit to discharge storm water, and the performance of any additional duties as defined by state and federal law.

(3) The ________________ [authorized enforcement agency] shall have the right to set up on any permitted facility such devices as are necessary in the opinion of the authorized enforcement agency to conduct monitoring and/or sampling of the facility's storm water discharge.

(4) The ________________ [authorized enforcement agency] has the right to require the discharger to install monitoring equipment as necessary. The facility's sampling and monitoring equipment shall be maintained at all times in a safe and proper operating condition by the discharger at its own expense. All devices used to measure stormwater flow and quality shall be calibrated to ensure their accuracy.

(5) Any temporary or permanent obstruction to safe and easy access to the facility to be inspected and/or sampled shall be promptly removed by the operator at the written or oral request of the ________________ [authorized enforce-

ment agency] and shall not be replaced. The costs of clearing such access shall be borne by the operator.

(6) Unreasonable delays in allowing the ______________________ [authorized enforcement agency] access to a permitted facility is a violation of a storm water discharge permit and of this ordinance. A person who is the operator of a facility with a NPDES permit to discharge storm water associated with industrial activity commits an offense if the person denies the authorized enforcement agency reasonable access to the permitted facility for the purpose of conducting any activity authorized or required by this ordinance.

(7) If the ______________________ [authorized enforcement agency] has been refused access to any part of the premises from which stormwater is discharged, and he/she is able to demonstrate probable cause to believe that there may be a violation of this ordinance, or that there is a need to inspect and/or sample as part of a routine inspection and sampling program designed to verify compliance with this ordinance or any order issued hereunder, or to protect the overall public health, safety, and welfare of the community, then the authorized enforcement agency may seek issuance of a search warrant from any court of competent jurisdiction.

Section 11. Requirement to Prevent, Control, and Reduce Storm Water Pollutants by the Use of Best Management.

[Authorized enforcement agency] will adopt requirements identifying Best Management Practices for any activity, operation, or facility which may cause or contribute to pollution or contamination of storm water, the storm drain system, or waters of the U.S. The owner or operator of a commercial or industrial establishment shall provide, at their own expense, reasonable protection from accidental discharge of prohibited materials or other wastes into the municipal storm drain system or watercourses through the use of these structural and non-structural BMPs. Further, any person responsible for a property or premise, which is, or may be, the source of an illicit discharge, may be required to implement, at said person's expense, additional structural and non-structural BMPs to prevent the further discharge of pollutants to the municipal separate storm sewer system. Compliance with all terms and conditions of a valid NPDES permit authorizing the discharge of storm water associated with industrial activity, to the extent practicable, shall be deemed compliance with the provisions of this section. These BMPs shall be part of a stormwater pollution prevention plan (SWPP) as necessary for compliance with requirements of the NPDES permit.

Section 12. Watercourse Protection.

Every person owning property through which a watercourse passes, or such person's lessee, shall keep and maintain that part of the watercourse within the property free of trash, debris, excessive vegetation, and other obstacles that would pollute, contaminate, or significantly retard the flow of water through the watercourse. In addition, the owner or lessee shall maintain existing privately owned structures within or adjacent to a watercourse, so that such structures will not become a hazard to the use, function, or physical integrity of the watercourse.

Section 13. Notification of Spills.

Notwithstanding other requirements of law, as soon as any person responsible for a facility or operation, or responsible for emergency response for a facility or operation has information of any known or suspected release of materials which are resulting or may result in illegal discharges or pollutants discharging into storm water, the storm drain system, or water of the U.S. said person shall take all necessary steps to ensure the discovery, containment, and cleanup of such release. In the event of such a release of hazardous materials said person shall immediately notify emergency response agencies of the occurrence via emergency dispatch services. In the event of a release of non-hazardous materials, said person shall notify the authorized enforcement agency in person or by phone or facsimile no later than the next business day. Notifications in person or by phone shall be confirmed by written notice addressed and mailed to the ______________________ [authorized enforcement agency] within three business days of the phone notice. If the discharge of prohibited materials emanates from a commercial or industrial establishment, the owner or operator of such establishment shall also retain an on-site written record of the discharge and the actions taken to prevent its recurrence. Such records shall be retained for at least three years.

Section 14. Enforcement.

1. Notice of Violation.

   Whenever the ______________________ [authorized enforcement agency] finds that a person has violated a prohibition or failed to meet a requirement of this Ordinance, the authorized enforcement agency may order compliance by written notice of violation to the responsible person. Such notice may require without limitation:

(a) The performance of monitoring, analyses, and reporting;

(b) The elimination of illicit connections or discharges;

(c) That violating discharges, practices, or operations shall cease and desist;

(d) The abatement or remediation of storm water pollution or contamination hazards and the restoration of any affected property; and

(e) Payment of a fine to cover administrative and remediation costs; and

(f) The implementation of source control or treatment BMPs.

If abatement of a violation and/or restoration of affected property is required, the notice shall set forth a deadline within which such remediation or restoration must be completed. Said notice shall further advise that, should the violator fail to remediate or restore within the established deadline, the work will be done by a designated governmental agency or a contractor and the expense thereof shall be charged to the violator.

Section 15. Appeal of Notice of Violation.

Any person receiving a Notice of Violation may appeal the determination of the authorized enforcement agency. The notice of appeal must be received within ___ days from the date of the Notice of Violation. Hearing on the appeal before the appropriate authority or his/her designee shall take place within 15 days from the date of receipt of the notice of appeal. The decision of the municipal authority or their designee shall be final.

Section 16. Enforcement Measures After Appeal.

If the violation has not been corrected pursuant to the requirements set forth in the Notice of Violation, or , in the event of an appeal, within ___ days of the decision of the municipal authority upholding the decision of the authorized enforcement agency, then representatives of the authorized enforcement agency shall enter upon the subject private property and are authorized to take any and all measures necessary to abate the violation and/or restore the property. It shall be unlawful for any person, owner, agent or person in possession of any premises to refuse to allow the government agency or designated contractor to enter upon the premises for the purposes set forth above.

Section 17. Cost of Abatement of the Violation.

Within _____ days after abatement of the violation, the owner of the property will be notified of the cost of abatement, including administrative costs. The property owner may file a written protest objecting to the amount of the assessment within _____ days. If the amount due is not paid within a timely manner as determined by the decision of the municipal authority or by the expiration of the time in which to file an appeal, the charges shall become a special assessment against the property and shall constitute a lien on the property for the amount of the assessment. Any person violating any of the provisions of this article shall become liable to the city by reason of such violation. The liability shall be paid in not more than 12 equal payments. Interest at the rate of _____ percent per annum shall be assessed on the balance beginning on the _____ st day following discovery of the violation.

Section 18. Injuctive Relief.

It shall be unlawful for any person to violate any provision or fail to comply with any of the requirements of this Ordinance. If a person has violated or continues to violate the provisions of this ordinance, the authorized enforcement agency may petition for a preliminary or permanent injunction restraining the person from activities which would create further violations or compelling the person to perform abatement or remediation of the violation.

Section 19. Compensatory Actions.

In lieu of enforcement proceedings, penalties, and remedies authorized by this Ordinance, the authorized enforcement agency may impose upon a violator alternative compensatory actions, such as storm drain stenciling, attendance at compliance workshops, creek cleanup, etc.

Section 20. Violations Deemed a Public Nuisance.

In addition to the enforcement processes and penalties provided, any condition caused or permitted to exist in violation of any of the provisions of this Ordinance is a threat to public health, safety, and welfare, and is declared and deemed a nuisance, and may be summarily abated or restored at the violator's expense, and/or a civil action to abate, enjoin, or otherwise compel the cessation of such nuisance may be taken.

Section 21. Criminal Prosecution.

Any person that has violated or continues to violate this ordinance shall be liable to criminal prosecution to the fullest extent of the law, and shall be subject to a criminal penalty of ______ dollars per violation per day and/or imprisonment for a period of time not to exceed _____ days. The authorized enforcement agency may recover all attorney's fees court costs and other expenses associated with enforcement of this ordinance, including sampling and monitoring expenses.

Section 22. Remedies Not Exclusive.

The remedies listed in this ordinance are not exclusive of any other remedies available under any applicable federal, state or local law and it is within the discretion of the authorized enforcement agency to seek cumulative remedies.

Section 23. Adoption of Ordinance.

This ordinance shall be in full force and effect __ days after its final passage and adoption. All prior ordinances and parts of ordinances in conflict with this ordinance are hereby repealed.

PASSED AND ADOPTED this _____ day of ________, 20____, by the following vote:

Stormwater Operation and Maintenance Model Ordinance

Unlike other model ordinances, the Operation and Maintenance ordinance language is not "stand-alone." Operation and Maintenance language would be a part of a broader stormwater ordinance.

Section I. Definitions

Stormwater Treatment Practice: Structural device, measure, facility, or activity that helps to achieve stormwater management control objectives at a designated site.

Site Stormwater Management Plan: A document approved at the site design phase that outlines the measures and practices used to control stormwater runoff at a site.

Section II. Design

1. All stormwater BMPs shall be designed in a manner to minimize the need for maintenance and reduce the chances of failure. Design guidelines are outlined in the most recent version of _________________ (local or state stormwater manual).

   Rather than incorporate specific stormwater design or maintenance standards into the ordinance itself, it is best to reference "the most recent version" of a stormwater manual. This way, technical information can remain up-to-date without making legal changes to the ordinance.

2. Stormwater easements and covenants shall be provided by the property owner for access for facility inspections and maintenance. Easements and covenants shall be recorded with (stormwater agency) prior to the issuance of a permit.
3. Final design shall be approved by (stormwater agency)

Section III. Routine Maintenance

1. All stormwater BMPs shall be maintained according to the measures outlined in the most recent version of _____________ (local or state stormwater manual), and as approved in the permit.
2. The person(s) or organization(s) responsible for maintenance shall be designated in the plan. Options include
   - Property owner
   - Homeowner's association, provided that provisions for financing necessary maintenance are included in deed restrictions or other contractual agreements
   - ________________ *(stormwater management agency)*
3. Maintenance agreements shall specify responsibilities for financing maintenance.

Section IV. Nonroutine Maintenance

1. Nonroutine maintenance includes maintenance activities that are expensive but infrequent, such as pond dredging or major repairs to stormwater structures.
2. Nonroutine maintenance shall be performed on an as-needed basis based on information gathered during regular inspections.
3. If nonroutine maintenance activities are not completed in a timely manner or as specified in the approved plan, ___________ (stormwater agency) may complete the necessary maintenance at the owner's/operator's expense.

Section V. Inspections

1. The person(s) or organization(s) responsible for maintenance shall inspect stormwater BMPs on a regular basis as outlined in the plan.

2. Authorized representatives of ___________________ *(stormwater agency)* may enter at reasonable times to conduct on-site inspections or routine maintenance.

3. For BMPs maintained by the property owner or homeowner's association, inspection and maintenance reports shall be filed with ______________________ *(stormwater agency)* as provided for in the plan.

4. Authorized representatives of ___________________inspections to confirm the information in the reports filed under Section V(3).

Model Ordinance for Stormwater Management[1]

Background

In 1991, the Connecticut General Assembly passed Public Acts 91-398 (amending CGS Section 8-23(a)) and 91-170 (amending CGS Sections 8-2(b), 8-3b and 8-35a). These acts require, in part, that zoning regulations and plans of conservation and development adopted by coastal municipalities be made with reasonable consideration for greater protection of Long Island Sound water quality. In particular, the Acts required municipalities to adopt regulations and plans with reasonable consideration and protection of the ecosystem and habitat of Long Island Sound and to design them to reduce hypoxia, pathogens, toxic contaminants and floatable debris in Long Island Sound. It is well documented that improperly managed stormwater flows do make significant contributions to coastal pollution, resulting in hypoxic (low dissolved oxygen) conditions and increases in pathogens, toxic contaminants and floatable debris. Therefore, improved stormwater management and treatment will result in decreases in these pollutants.

In order to assist municipalities in meeting the substantive as well as legal requirements of this legislation, the Connecticut Department of Environmental Protection's Office of Long Island Sound Programs developed this Model Stormwater Ordinance for municipal use. The approach of providing a model ordinance as opposed to zoning regulations was selected due to the need for consistent approaches to stormwater management in various municipal regulations such as zoning regulations, wetlands regulations, coastal site plan review and aquifer protection regulations. Thus, rather than provide model site plan regulations, which may conflict with existing municipal regulations, an ordinance provides a more appropriate means of ensuring consistency among various municipal regulations.

Depending upon the current format of your regulations, portions of this ordinance can be inserted where appropriate. Therefore, the first task is to identify appropriate sections. For example, should your regulations have an environmental section, this may be the most appropriate place for incorporation; however, you may have a drainage section that would be more appropriate. Since the system of regulations varies from town to town, this model may have to be reorganized in order to match an existing format. Prior to adopting any stormwater regulations, the municipality's corporation counsel should be consulted.

Although this model ordinance was initially developed for use by coastal municipalities in meeting a legislative requirement, it is clear that stormwater must be better controlled statewide. Therefore, all Connecticut municipalities can adopt this ordinance, which can also help municipalities meet requirements contained in state stormwater general permits for municipal separate stormwater sewer systems. In reviewing the model ordinance, please note that suggested ordinance language is in normal type; explanations or commentary are in italics.

Purpose and Authority

In accordance with the provisions of Chapters 98, 124, 126, 440, 444, and 446h of the General Statutes of the State of Connecticut, as amended, the Town of __________ hereby adopts the following Stormwater Management Ordinance for the following purposes:

Increased development without proper consideration of stormwater impacts can be a significant source of pollution to Long Island Sound, its tributaries, and other waters of the state. The state's water resources are valuable natural, economic, recreational, cultural and aesthetic resources. The protection and preservation of these waters is in the public interest and is essential to the health, welfare and safety of the citizens of the state. It is, therefore, the purpose of this ordinance to protect and preserve the waters within (town name) from nonpoint sources of pollution through the proper management of stormwater flows and minimization of inputs of suspended solid, pathogens, toxic contaminants, nitrogen and floatable debris to these flows.

[1]Excertpted from *Coastal Water Quality Protection: A Guide for Local Officials* (DEP, 1996).

Definitions

aquifer – a geologic formation, group of formations or part of a formation that contains sufficient saturated, permeable materials to yield significant quantities of water to wells and springs

BMPs – best management practices - techniques or structural devices that are effective practical ways of preventing or reducing pollution

"first inch of rain" – the first inch of rainfall during a single event. The initial runoff from the first inch of rain contains higher pollutant concentrations than the subsequent runoff, due to initial washing off of dry weather deposits in significantly higher concentrations than those washed off later in a storm. This effect is particularly pronounced with initial heavy rainfalls.

groundwater – water found beneath the ground surface that completely fills the open spaces between particles of sediment and within rock formations

impervious surface – material or structure on, above or below the ground that does not allow precipitation or surface water to penetrate directly into the soil

site – a single parcel, together with any adjacent waters, which is the subject of an application for zoning approval, subdivision approval, coastal site plan review, or an inland wetlands permit

sediment – solid material, either mineral or organic, that is in suspension, is transported, or has been moved from its site or origin by erosion

trash hood – feature in a catch basin which traps debris such as litter and keeps it from being discharged from the catch basin

urban stormwater runoff – precipitation that falls onto the surfaces of roofs, streets, parking lots, roads and the grounds of developed areas. Urban precipitation is not absorbed by the ground or retained in its surface, but collects and runs off, carrying a wide variety of pollutants such as oil-based contaminants, heavy metals (copper and lead), nutrients and bacteria

Application Requirements

Stormwater management plans should be strongly encouraged for all land use and development projects, even where they are not required. A stormwater management plan shall be included as a part of any application for zoning approval, subdivision approval, coastal site plan review, or an inland wetlands permit where:

1. the application pertains to a development or construction project disturbing one or more acres of total land area on a site; *Applicants should be made aware that any development which calls for a total disturbance of over 5 acres also requires the submission of registration to the Connecticut DEP under the General Permit for the Discharge of Stormwater and Dewatering Wastewaters from Construction Activities.*
2. the application pertains to any site with one acre or more of impervious cover;
3. the application proposes new residential development of three or more units;
4. the application pertains to any new industrial or commercial project; or
5. the commission which has jurisdiction over the application has required submission of a stormwater management plan pursuant to written findings that the activity proposed in the application has the potential to cause significant nonpoint source pollution to groundwater or surface water drinking supplies, or to Long Island Sound or any other waters of the state. Such findings may be based upon a written request by the Commissioner of Environmental Protection.

If the commission determines that the activity proposed in an application may result in significant nonpoint source pollution to groundwater or surface water drinking supplies, or to Long Island Sound or any other waters of the state, it may refer the application, including the stormwater management plan, to the Commissioner of Environmental Protection for a determination as to whether a discharge permit under section 22a-430 of the General Statutes, or other state authorization, is required.

Contents of stormwater management plan:

Where a stormwater management plan is required, such plan shall provide, at a minimum, the following information:

1. Soil characteristics of the site.
2. Location of the closest surface water bodies and wetlands to the site, and the depth to any groundwater or aquifer areas on or adjacent to the site. In the case of tidal waters, provide the mean high water and high tide elevations.
3. DEP ground and surface water quality classification of waterbodies on and adjacent to the site.
4. Identification of any waterbodies on and adjacent to the site documented by DEP as not meeting water quality standards. *The list of impaired waterbodies, documented by DEP pursuant to Section 303(d) of the Federal Clean Water Act, and can be accessed online at http://www.dep.state.ct.us/wtr/wq/impaired 2002.pdf*

5. Location and description of all proposed stormwater control BMPs for both construction activities and post-construction long-term stormwater control.

6. Proposed maintenance and operation manual or schedule for any trash hoods, catchbasins, or other BMP devices used to prevent runoff, encourage sheet flow or infiltration, or treat stormwater.

7. Calculations of stormwater runoff rates, suspended solids removal rates, and soil infiltration rates before and after completion of the activity proposed in the application.

8. A hydrologic study of pre-development site conditions. Hydrology studies shall be conducted at a level of detail commensurate with the probable impact of the proposed activity and should extend downstream to the point where the proposed activity causes less than a five percent change in the peak flow rates.

Standards and Criteria for Decision

In order to approve any application for which a stormwater management plan is required, the commission shall find the stormwater management plan consistent with the following criteria. If such application is also subject to the requirements of an aquifer protection overlay zone or any other requirements for nonpoint source pollution control, the more stringent requirements shall control.

1. Direct channeling of untreated surface water runoff into adjacent ground and surface waters shall be prohibited.

2. No net increase in urban stormwater runoff from the site, to the maximum extent possible, shall result from the proposed activity.

3. Design and planning for site development shall provide for minimal disturbance of pre-development natural hydrologic conditions, and shall reproduce such conditions after completion of the proposed activity, to the maximum extent feasible.

4. Pollutants shall be controlled at their source to the maximum extent feasible in order to contain and minimize contamination. S*uch an approach is not only cost-effective but more efficient, by reducing the need for extensive restoration efforts. Methods include but are not limited to sweeping of streets and parking lots, especially in the early spring, the use of oil traps and sediment basins prior to infiltration, the use of pervious surfaces and encouragement of sheet flow to filter strips.*

5. Stormwater management systems shall be designed and maintained to manage site runoff in order to eliminate surface and groundwater pollution, prevent flooding and, where required, control peak discharges and provide pollution treatment.

6. Stormwater management systems shall be designed to collect, retain and treat the first inch of rain on-site, so as to trap floating material, oil and litter. *BMP techniques to achieve treatment of the first inch of rainfall include oil and grit separators, and trash hoods.*

7. On-site storage of stormwater shall be employed to the maximum extent feasible. *On-site storage methods include but are not limited to landscaped depressions, grass swales, infiltration trenches and retention or detention basins.*

8. Post-development runoff rates and volumes shall not exceed pre-development rates and volumes. Stormwater runoff rates and volumes shall be controlled by slowing runoff velocities and encouraging infiltration. *BMP methods for controlling runoff and encouraging infiltration include the minimization of impervious surfaces, minimization of curbing and collection, the use of grass or vegetative filter zones, landscape depressions, slotted curb spacers, perforated pipes for conveying stormwater, establishment of buffers from streams, wetlands and waterbodies, and any combination of methods, where appropriate.*

9. Stormwater treatment systems shall be employed where necessary to ensure that the average annual loadings of total suspended solids (TSS) following the completion of the proposed activity at the site are no greater than such loadings prior to the proposed activity. Alternatively, stormwater treatment systems shall remove 80% of TSS from the site on an average annual basis. *BMP methods for stormwater treatment include infiltration through vegetative strips, grass swales and detention basins.*

Excerpts from Local Regulations

From Cromwell SECTION XI – SPECIAL REGULATIONS

11.2 STORMWATER RUNOFF CONTROL REGULATION

a. Stormwater Runoff Control Plans. Site Plans shall be accompanied by plans providing measures for detention and controlled release of stormwater runoff when proposed developments contain an area of five (5) acres or more or the impervious area is 60.0% or greater. All other developments may be required to provide such measures if deemed necessary to protect the public health, safety and well-being by the Planning and Zoning

Commission.

1. When required, measures for the detention and controlled release of stormwater runoff shall meet the following standards:

a. Release rate shall not exceed the rate of runoff for the same site in its undeveloped state for all intensities and durations of rainfall.

b. Required volume for stormwater detention shall be calculated on the basis of runoff from a 50-year frequency rainfall, as published by the National Weather Service or other recognized agency. The detention volume required shall be that necessary to handle the runoff of a 50-year frequency rainfall, for any and all durations, from the proposed development less that volume discharged during the same duration at the approved release rate as specified above.

c. In all cases, runoff shall be computed in accordance with *Technical Release #55,* Engineering Division, Soil Conservation Service, USDA, January, 1975, as amended.

2. The ability to retain and maximize the ground water recharge capacity is encouraged. Design of the stormwater runoff control system shall give consideration to providing ground water recharge.

3. All on-site facilities shall be properly maintained by the owner such that they do not become nuisances.

4. All runoff control structures located on private property shall be accessible at all times for Town inspection.

From Cromwell, Section 300 Regulations, j. STORMWATER RUNOFF CONTROL:

The use of "best management practices" (BMPs) to minimize nonpoint source pollution shall be considered by the applicant, including but not limited to thoseBMPs discussed in the "Nonpoint Source Pollution Management Plan for the Town of Cromwell" dated October 1992. A written description of this consideration shall be submitted with the application.

From East Lyme Plan of Conservation and Development, Section Seven - Transportation

From Parking Recommendations:

Promote the use of permeable lot paving materials that will reduce surface water runoff into the municipal waste water treatment system. Best management practices for roads and parking areas should be examined to include minimized use of curbing where appropriate, minimized disturbance when building new or improving existing roads, minimizing impervious surfaces in new roads and parking areas, regular sweeping of parking areas and roadways and routine catch basin maintenance.

From Enfield, ARTICLE X SITE DEVELOPMENT REGULATIONS

Section 10.10 Off Street Parking and Loading Regulations

10.10.6 Parking Design, Layout, and Location

(The standards of this section shall apply to all parking areas that serve three (3) or more vehicles or two (2) or more uses.)

All off street parking areas and driveways shall be designed, to include drainage design, and constructed to the standards of the Director of Public Works. The Commission may allow an alternate surface to be used for the parking area when such surface is designed to minimize storm water runoff. In such situations, a maintenance plan for the surface must be approved by the Commission.

From Farmington Zoning Regulations: Article IV, Special Regulations

Section 25. STORMWATER SYSTEMS

A. Stormwater systems designed and installed in conjunction with the development of land must receive the approval of the Commission in consultation with the Town Engineer.

B. Stormwater systems shall be designed for the following objectives:

1. Prevent flooding of onsite or offsite property.

2. Feed and recharge inland wetlands, surface and subsurface waters.

3. Minimize pollutant loads in stormwater runoff into inland wetlands, surface and subsurface waters.

4. Maintain the hydrology of existing sub watersheds including wetlands and watercourses.

C. The Commission may withhold the approval of a storm water system design if it fails to meet the above objectives.

D. The maintenance of a private storm water system is the responsibility of the property owner. The Commission may require that a maintenance program be developed and submitted to them for approval. The Commission may require that a bond be posted and/or that periodic reports be filed with the Town to ensure that the required maintenance has been performed.

From Glastonbury, Zoning Regulations 10.0 Street and Highway Standards

Where permanent cul-de-sac streets are included in a residential subdivision, they shall not exceed fifteen hundred (1500) feet in length. A permanent cul-de-sac shall contain a turnaround which has a minimum right-of-way radius of fifty-five (55) feet and a minimum outside pavement radius of forty-five (45) feet except where a permanent cul-de-sac has classification "Light Local" or "Limited Local" the Commission may permit a turnaround which has a minimum right-of-way radius of fifty (50) feet and a minimum outside pavement radius of forty-five (45) feet. A twenty-five (25) foot pavement width shall be provided around cul-de-sac islands located on "Light Local" or "Limited Local" streets. Low maintenance cul-de-sac islands may be permitted.

From South Windsor Zoning Regulations: SECTION XIII: OFF-STREET PARKING AND LOADING

13.4.1 Modification of Minimum Required Parking Spaces

A reduction in parking spaces will be allowed when the Planning and Zoning Commission deems the reduction to be in the best interest of the Town, according to the following:

a. The changes in topography of the land can be minimized by reducing the number of parking spaces.

b. The cutting of trees and other desirable plants can be minimized by reducing the number of parking spaces.

c. The increase in stormwater run-off rate shall be held to a minimum by reducing the parking spaces.

From Windsor Zoning Regulations SECTION V: USE REGULATIONS, COMMERCIAL ZONES, I-291 CORRIDOR DEVELOPMENT ZONE

5.9.6 Infrastructure Improvements

5.9.6.D Stormwater Management

1. Design of the stormwater management system shall be consistent with the standards of the Public Improvement Specifications manual. Zero net increase in stormwater runoff (ZIRO) between pre- and post-development conditions is to be maintained for the 2, 10, 25 and 100 year storms, unless it can be demonstrated that there will be no deleterious downstream effects.

2. The applicant shall employ the best available technology in design of the closed drainage system, including oil and sediment separation devices, filtration and discharge techniques.

   The Town encourages the use of on-site natural filtration functions as a part of currently accepted Best Management Practices in the reduction of sediment and pollutants.

3. The applicant shall employ, as appropriate, the extended wet-bottom detention basin technique for metering site generated storm runoff prior to discharge to off-site drainage systems.

   When accessible, the applicant shall utilize Town-owned lands for construction of the wet basin. Such basins will be ultimately sized to accommodate more than one user. Where location of a detention facility on Town land is not feasible due to distance or access problems, the applicant is encouraged to enter into an easement agreement with adjacent lots to create a shared-use detention facility. Consolidated parcels will share a detention facility.

4. Clean Water: Clean water is defined as that stormwater runoff generated from roof flows collected in roof gutter or other pickup systems and transported via risers to underground pipes and out to a discharge point. These flows may not need to be attenuated (meet ZIRO requirements) if the volume of runoff can be dissipated by infiltration into the groundwater table.

5. Dirty Water: Dirty water is defined as that storm runoff generated from parking and road pavements that carry sands, road salts, oils, etc. These flows are initially treated at catch basins where some heavy particulates are trapped in basin sumps. Prior to discharge, flows will pass through a "water quality inlet" where sediment and oil chambers can provide for secondary separation of particulates and oils. Discharges would then either be directed offsite or into a wet detention basin in accordance with ZIRO requirements for that portion of the site.

From Windsor Zoning Regulations SECTION 3. SITE DEVELOPMENT

3.4 OFF-STREET PARKING

3.4.1 General Provisions

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The Commission may, depending on the parking needs of a particular use, authorize a phased development of the off-street parking area in compliance with the following criteria:

1. The total number of spaces required to be shown on the Site Plan shall be determined in accordance with the standards for that particular use.
2. The construction of the parking area and installation of the spaces may be phased according to short- and long-term needs of a particular use. Not less than 50 percent of the total required spaces shall be constructed as part of the short term, except that for buildings housing computer equipment and operations, and for wholesale or warehouse uses, this percentage may be reduced to not less than 30 percent. This approval shall become null and void if the use changes.
3. The spaces which are not intended for construction as part of the short term shall be labeled "Reserve Parking" on the plan and shall be properly designed and shown as an integral part of the overall parking layout and must be located on land suitable for parking area development.
4. If at any time after the Certificate of Use and Occupancy is issued the Zoning Enforcement Officer determines that additional spaces may be needed, he shall notify the Commission and the owner of the property concerning his finding.
5. The Commission may, after reviewing the Zoning Enforcement Officer's report, require that all or any portion of the spaces shown on the approved Site Plan as "Reserve Parking" be constructed.

From Woodbury Subdivision Regulations, SECTION IV - DESIGN AND CONSTRUCTION STANDARDS

4.18 Watershed/Viewshed Regulated Area (Effective 4/1/98)

4.18.1 Intent: The Watershed/Viewshed Regulated Area is adopted in order to:

a. Promote the goals and objectives of the Woodbury Plan of Conservation and Development.

b. Encourage the most appropriate use of land.

c. Preserve the natural environment of distinctive ridgeline areas as a visual and historic asset for the benefit of the community.

d. Protect the groundwater recharging function and capacity of the ridges by minimizing the potential for pollution and preserving open areas for groundwater recharge.

e. Prevent the creation of any safety or health hazard including, but not limited to, soil erosion, excessive drainage runoff, and degradation of water quality.

f. Minimize the adverse effect of development upon both the visual and functional role of the natural landscape to preserve Woodbury's quality of life.

Appendix D

Site Stormwater Management Plan Checklist

1. Applicant/Site Information

Applicant name, legal address, telephone/fax numbers

Common address and legal description of site

Site locus map

2. Project Narrative

Project description and purpose (for existing and proposed conditions)

- ❍ *Natural and manmade features at the site, including, at a minimum, wetlands, watercourses, floodplains, and development (roads, buildings, and other structures)*
- ❍ *Site topography, drainage patterns, flow paths, and ground cover*
- ❍ *Impervious area and runoff coefficient*
- ❍ *Site soils as defined by USDA soil surveys including soil names, map unit, erodibility, permeability, depth, texture, and soil structure*
- ❍ *Stormwater discharges from the site, including quality and known sources of pollutants and sediment loadings*
- ❍ *Critical areas, buffers, and setbacks established by the local, state, and federal regulatory authorities*
- ❍ *Water quality classification of on-site and adjacent waterbodies*
- ❍ *Identification of any on-site or adjacent waterbodies included on the Connecticut 303(d) list of impaired waters*

Potential stormwater impacts

- ❍ *Potential pollution sources (e.g., erosive soils, steep slopes, vehicle fueling, vehicle washing)*
- ❍ *Types of anticipated stormwater pollutants and the relative or calculated load of each pollutant*
- ❍ *Summary of calculated pre- and post-development peak flows*
- ❍ *Summary of calculated pre- and post-development groundwater recharge*

Critical on-site resources

- ❍ *Wells, aquifers*
- ❍ *Wetlands, streams, ponds*
- ❍ *Public drinking water supplies*

Critical off-site (adjacent to or downstream of site) resources

- ❍ *Neighboring land uses*
- ❍ *Wells, aquifers*
- ❍ *Wetlands, streams, ponds*
- ❍ *Public drinking water supplies*

Proposed stormwater management practices

- ❍ *Source controls and pollution prevention*
- ❍ *Alternative site planning and design*
- ❍ *Stormwater treatment practices*
- ❍ *Flood control and peak runoff attenuation management practices*

Site plan (for existing and proposed conditions) (see Item 4. below for appropriate format)

- ❍ *Topography, drainage patterns, drainage boundaries, and flow paths*
- ❍ *Locations of stormwater discharges*
- ❍ *Perennial and intermittent streams*
- ❍ *USDA soil types*
- ❍ *Proposed borehole investigations*
- ❍ *Vegetation and proposed limits of clearing and disturbance*
- ❍ *Resource protection areas such as wetlands, lakes, ponds, and other setbacks (stream buffers, drinking water well setbacks, septic setbacks, etc.)*
- ❍ *Roads, buildings, and other structures*
- ❍ *Utilities and easements*
- ❍ *Temporary and permanent conveyance systems (grass channels, swales, ditches, storm drains, etc.) including grades, dimensions, and direction of flow*
- ❍ *Location of floodplain and floodway limits and relationship of site to upstream and downstream properties and drainage systems*
- ❍ *Location, size, maintenance access, and limits of disturbance of proposed structural stormwater management practices (treatment practices, flood control facilities, stormwater diversion structures, etc.)*
- ❍ *Final landscaping plans for structural stormwater management practices and site revegetation*

- *Locations of non-structural stormwater management practices (i.e., source controls)*

Construction Schedule

3. Calculations

Pollutant Reduction

- *Water Quality Volume (WQV)*
- *Water Quality Flow (WQF)*
- *Pollutant Loads*

Groundwater Recharge

- *Groundwater Recharge Volume (GRV)*

Runoff Capture (for new stormwater discharges to tidal wetlands)

- *Runoff Capture Volume*

Peak Flow Control

- *Hydrologic and hydraulic design calculations (pre- and post-development conditions)*
    - *Description of the design storm frequency, intensity, and duration*
    - *Watershed map with locations of design points and watershed areas (acres) for runoff calculations*
    - *Time of concentration (and associated flow paths)*
    - *Imperviousness of the entire site and each watershed area*
    - *NRCS runoff curve numbers or volumetric runoff coefficients*
    - *Peak runoff rates, volumes, and velocities for each watershed area (24-hour storm)*
        - *Stream Channel Protection: 2-year frequency ("over-control" of 2-year storm)*
        - *Conveyance Protection: 10-year frequency*
        - *Peak Runoff Attenuation: 10-year, 25-year, and 100-year frequency (other as required by local review authority)*
        - *Emergency Outlet Sizing: safely pass the 100-year frequency or larger storm*
    - *Hydrograph routing calculations*
    - *Culvert capacities*
    - *Infiltration rates, where applicable*
    - *Dam breach analysis, where applicable*
    - *Documentation of sources for all computation methods and field test results*
- *Downstream analysis, where detention is proposed*
- *Drainage systems and structures*

4. Design Drawings and Specifications

Recommended size (no larger than 24" x 36" and no smaller than 8-1/2" x 11")

Recommended scale (maximum scale of 1" = 40', larger scales up to 1" = 100' may be used to represent overall site development plans or for conceptual plans)

Design details (cross-sections, elevation views, and profiles as necessary)

Specifications

- *Construction materials*
- *Stormwater control product designations (if applicable)*
- *Methods of installation*
- *Reference to applicable material and construction standards*

Cover sheet with sheet index

Title block

Legend

North arrow

Property boundary of subject property (including parcels, or portions thereof, of abutting land and roadways within one hundred feet of the property boundary)

Site locus map (recommended scale 1" = 1,000') with a north arrow

Seals of licensed professionals (original design plans, calculations, and reports)

Survey plans

- *Prepared according to the Minimum Standards for Surveys and Maps in Connecticut*
- *The class of survey represented on the plan*
- *Stamped by a professional land surveyor*
- *Depict topography at contour intervals of two feet*

- *The referenced or assumed elevation datum*
- *Two (2) benchmarks on the site within one hundred feet of the proposed construction*
- *Outside limits of disturbances*
- *Plan references*

5. Construction Erosion and Sediment Controls

Erosion and sediment control plan that complies with the requirements of the current version of *Connecticut Guidelines for Soil Erosion and Sediment Control*, DEP Bulletin 34.

6. Supporting Documents and Studies

Provide other sources of information used in the design of construction and post-construction stormwater controls for the site development, as applicable:

Soil maps, borings/test pits

Infiltration test results

Groundwater impacts for proposed infiltration structures

Reports on wetlands and other surface waters (including available information such as Maximum Contaminant Levels [MCLs], Total Maximum Daily Loads [TMDLs], 303(d) or 305(b) listings, etc.)

Water quality impacts to receiving waters and biological/ecological studies

Flood study/calculations

7. Other Required Permits

Evidence of acquisition of all applicable federal, state, and local permits or approvals (e.g., copies of DEP permit registration certificates, DEP Dam Safety Registration certificate for stormwater impoundments, DPH approval letter for stormwater discharges within 100 feet of a watercourse within a public water supply watershed or aquifer protection area, local approval letters, etc.)

8. Operation and Maintenance

Detailed inspection and maintenance requirements/tasks

Inspection and maintenance schedules

Parties legally responsible for maintenance (name, address, and telephone number)

Provisions for financing of operation and maintenance activities

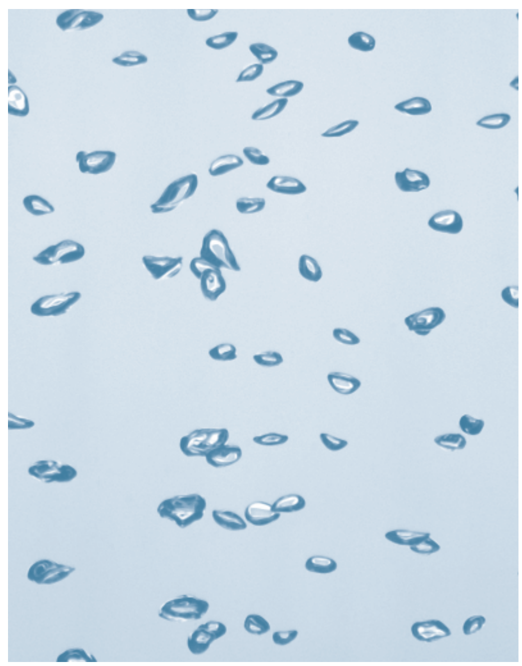
As-built plans of completed structures

Letter of compliance from designer

Post-construction documentation to demonstrate compliance with maintenance activities.

Appendix E

Maintenance Inspection Checklist



Stormwater Ponds and Wetlands

Project/Location: ______________________________

"As Built" Plans Available? ______________________________

Date/Time: ______________________________

Days Since Previous Rainfall and Rainfall Amount: ______________________________

Inspector: ______________________________

Maintenance Item	Satisfactory	Unsatisfactory	Comments
1. Embankment and Emergency Spillway			
○ Vegetation and ground cover adequate			
○ Embankment erosion			
○ Animal burrows			
○ Unauthorized planting			
○ Cracking, bulging, or sliding of embankment/dam			
a. Upstream face			
b. Downstream face			
c. At or beyond toe			
d. Emergency spillway			
○ Pond, toe & chimney drains clear and functioning			
○ Seeps/leaks on downstream face			
○ Slope protection or riprap failure			
○ Vertical/horizontal alignment of top of dam "As-Built"			
○ Emergency spillway clear of obstructions and debris			
○ Other (specify)			
2. Riser and Principal Spillway			
○ Low flow orifice obstructed			
○ Low flow trash rack obstructed with debris			
○ Weir trash rack obstructed with debris			
○ Excessive sediment accumulation insider riser			
○ Concrete/masonry condition riser and barrels			
a. Cracks or displacement			
b. Minor spalling (<1")			
c. Major spalling (rebars exposed)			
d. Joint failures			
e. Water tightness			
○ Metal pipe condition			

Maintenance Item	Satisfactory	Unsatisfactory	Comments
❍ Control valve			
a. Operational/exercised			
b. Chained and locked			
❍ Pond drain valve			
a. Operational/exercised			
b. Chained and locked			
❍ Outfall channels functioning			
❍ Other (specify)			
3. Permanent Pool (Wet Ponds)			
❍ Undesirable vegetative growth			
❍ Floating or floatable debris removal required			
❍ Visible pollution			
❍ Shoreline problem			
❍ Other (specify)			
4. Sediment Forebay			
❍ Sedimentation noted			
❍ Greater than 50% of storage volume remaining			
5. Dry Pond Areas			
❍ Vegetation coverage adequate			
❍ Undesirable vegetative growth			
❍ Undesirable woody vegetation			
❍ Low flow channels clear of obstructions			
❍ Standing water or wet spots			
❍ Sediment and/or trash accumulation			
❍ Other (specify)			
6. Condition of Outfalls			
❍ Riprap failures			
❍ Slope erosion			
❍ Storm drain pipes			
❍ Endwalls/Headwalls			
❍ Other (specify)			
7. Other			
❍ Complaints from residents (odors, insects, other)			
❍ Aesthetics (graffiti, algae, other)			
❍ Conditions of maintenance access routes			
❍ Signs of hydrocarbon build-up			
❍ Any public hazards (specify)			

Maintenance Item	Satisfactory	Unsatisfactory	Comments
8. Wetland Vegetation			
❍ Vegetation healthy and growing			
❍ Wetland maintaining 50% surface area coverage of wetland plants after the second growing season. (If unsatisfactory, reinforcement plantings needed)			
❍ Survival of desired wetland plant species distribution according to landscaping plan?			
❍ Evidence of invasive species			
❍ Maintenance of adequate water depths for desired wetland plant species.			
❍ Harvesting of emergent plantings needed			
❍ Have sediment accumulations reduced pool volume significantly or are plants choked with sediment?			
❍ Other (specify)			
Actions to Be Taken:			
To Be Completed By (Date):			

Source: Adapted from Watershed Management Institute, Inc. 1997. *Operation, Maintenance, and Management of Stormwater Management Systems,* in cooperation with U.S. Environmental Protection Agency, Office of Water. Washington, D.C.

Infiltration Basins and Trenches

Project/Location: ______________________________

"As Built" Plans Available? ______________________________

Date/Time: ______________________________

Days Since Previous Rainfall and Rainfall Amount: ______________________________

Inspector: ______________________________

Maintenance Item	Satisfactory	Unsatisfactory	Comments
1. Debris Cleanout			
○ Basin bottom or trench surface clear of debris			
○ Inlet/Inflow pipes clear of debris			
○ Overflow spillway clear of debris			
○ Outlet clear of debris			
2. Sediment Traps or Forebays			
○ Sedimentation noted			
○ Greater than 50% of storage volume remaining			
3. Vegetation (Basins)			
○ Mowing performed as necessary			
○ No evidence of erosion			
4. Dewatering			
○ Basin/Trench dewaters between storms			
○ Drawdown time does not exceed 36 to 48 hours			
5. Sediment Accumulation			
○ Approximate depth of accumulated sediment			
6. Inlets			
○ Good condition			
○ No evidence of erosion			
7. Outlet/Overflow Spillway			
○ Good condition, no need for repair			
○ No evidence of erosion			
8. Aggregate Repairs (Trench)			
○ Surface of aggregate clean			
○ Top layer of stone does not need replacement			
○ Trench does not need rehabilitation			

Maintenance Item	Satisfactory	Unsatisfactory	Comments
9. Structural Repairs			
❍ Embankment in good repair			
❍ Site slopes are stable			
❍ No evidence of erosion			
10. Fences/Access Repairs			
❍ Fences in good condition			
❍ No damage which would allow undesired entry			
❍ Access point in good condition			
❍ Locks and gate function property			
Actions to Be Taken:			
To Be Completed By (Date):			

Source: Adapted from Watershed Management Institute, Inc. 1997. Operation, Maintenance, and Management of Stormwater Management System,. in cooperation with U.S. Environmental Protection Agency, Office of Water. Washington, D.C.

Filtering Practices – Sand and Organic Filters

Project/Location: ______________________________

"As Built" Plans Available? ______________________________

Date/Time: ______________________________

Days Since Previous Rainfall and Rainfall Amount: ______________________________

Inspector: ______________________________

Maintenance Item	Satisfactory	Unsatisfactory	Comments
1. Debris Cleanout			
❍ Filtration facility clean of debris			
❍ Inlet and outlets clear of debris			
2. Oil and Grease			
❍ No evidence of filter surface clogging			
❍ Activities in drainage area minimize oil and grease entry			
3. Vegetation			
❍ Contributing drainage area stabilized			
❍ No evidence of erosion			
❍ Area mowed and clipping removed			
4. Water Retention			
❍ Water holding chambers at normal pool			
❍ Filter chamber dewaters between storms			
❍ No evidence of leakage			
5. Sediment Accumulation			
❍ Approximate depth of accumulated sediment			
❍ Depth of sediment in forebay or sump should not be more than 12 inches or 10 percent of the pretreatment volume			
❍ Sediment accumulation on filter bed does not exceed 1" or drawdown time does not exceed 36 to 48 hours			
6. Structural Components			
❍ No evidence of structural deterioration			
❍ Grates are in good condition			
❍ No evidence of spalling or cracking of structural parts			
7. Outlet/Overflow Spillway			
❍ Good condition, no need for repairs			
❍ No evidence of erosion (if draining into a natural channel)			

Maintenance Item	Satisfactory	Unsatisfactory	Comments
8. Overall Function of Facility			
❍ No evidence of flow bypassing facility			
❍ No noticeable odors outside facility			
Actions to Be Taken:			
To Be Completed By (Date):			

Source: Adapted from Watershed Management Institute, Inc. 1997. Operation, Maintenance, and Management of Stormwater Management Systems, in cooperation with U.S. Environmental Protection Agency, Office of Water. Washington, D.C.

Filtering Practices - Bioretention

Project/Location: ______________________________

"As Built" Plans Available? ______________________________

Date/Time: ______________________________

Days Since Previous Rainfall and Rainfall Amount: ______________________________

Inspector: ______________________________

Maintenance Item	Satisfactory	Unsatisfactory	Comments
1. Debris Cleanout			
❍ Bioretention and contributing areas clean of debris			
❍ No dumping of yard wastes into practice			
❍ Litter (branches, etc.) has been removed			
2. Vegetation			
❍ Plant height not less than design water depth			
❍ Fertilized per specifications			
❍ Plant composition according to approved plans			
❍ No placement of inappropriate plants			
❍ Grass height not greater than 6 inches			
❍ No evidence of erosion			
3. Check Dams/Energy Dissipaters/Sumps			
❍ No evidence of sediment buildup			
❍ No evidence of erosion at downstream toe of drop structure			
4. Dewatering			
❍ Dewaters between storms			
❍ No evidence of standing water			
5. Sediment Accumulation			
❍ Approximate depth of accumulated sediment			
❍ Depth of sediment in forebay or sump should not be more than 12 inches or 10 percent of the pretreatment volume			
❍ Sediment accumulation on filter bed does not exceed 1" or drawdown time does not exceed 36 to 48 hours			

Maintenance Item	Satisfactory	Unsatisfactory	Comments
6. Outlet/Overflow Spillway			
❍ Good condition, no need for repair			
❍ No evidence of erosion			
❍ No evidence of any blockages			
7. Integrity of Filter Bed			
❍ Filter bed has not been blocked or filled inappropriately			
Actions to Be Taken:			
To Be Completed By (Date):			

Source: Adapted from Watershed Management Institute, Inc. 1997. *Operation, Maintenance, and Management of Stormwater Management Systems*, in cooperation with U.S. Environmental Protection Agency, Office of Water. Washington, D.C.

Water Quality Swales

Project/Location: ______________________________

"As Built" Plans Available? ______________________________

Date/Time: ______________________________

Days Since Previous Rainfall and Rainfall Amount: ______________________________

Inspector: ______________________________

Maintenance Item	Satisfactory	Unsatisfactory	Comments
1. Debris Cleanout			
❍ No excessive trash and debris in contributing areas, forebay, or channel			
2. Check Dams or Energy Dissipators			
❍ No evidence of flow going around structures			
❍ No evidence of erosion at downstream toe			
3. Vegetation			
❍ Mowing performed as necessary (to maintain grass height of 4 to 6 inches during growing season)			
❍ No evidence of erosion (channel bottom or side slopes)			
❍ Fertilized per specification			
4. Dewatering			
❍ Dewaters between storms (dry swales)			
5. Sediment Accumulation			
❍ Approximate depth of accumulated sediment			
❍ Sediment accumulation is less than 25% of forebay or channel capacity (cleaning recommended otherwise)			
6. Outlet/Overflow Spillway			
❍ Good condition, no need for repairs			
❍ No evidence of erosion			
Actions to Be Taken:			
To Be Completed By (Date):			

Source: Adapted from Watershed Management Institute, Inc. 1997. Operation, Maintenance, and Management of Stormwater Management Systems, in cooperation with U.S. Environmental Protection Agency, Office of Water. Washington, D.C.

Appendix F
Glossary

Some definitions in this glossary are adapted from definitions in applicable sections of the Connecticut General Statutes and the Regulations of Connecticut State Agencies, as well as related guidance documents such as the *Connecticut Guidelines for Soil Erosion and Sediment Control*. Refer to these sources for complete definitions.

Advanced Treatment
Pollutant removal techniques typically used in drinking water treatment processes but with potential for application as advanced treatment options for stormwater. These treatment techniques include ion exchange, reverse osmosis, disinfection, ultrafiltration, alum injection, and use of water-soluble anionic polyacrylamide (PAM).

Agricultural Runoff
Runoff from land utilized for agricultural practices including growing crops and raising livestock.

Alternative Site Design
Innovative site design practices have been developed as alternatives to traditional development to control stormwater pollution and protect the ecological integrity of developing watersheds. Research has demonstrated that alternative site design can reduce impervious cover, runoff volume, pollutant loadings, and development costs when compared to traditional development.

Alum Injection
Injection of aluminum phosphate (alum), which has been used extensively as a flocculent in pond and lake management applications, for reducing concentrations of fine sediment and phosphorus in stormwater discharges to eutrophic water bodies.

Aquatic Bench
A ten-foot wide bench located around the inside perimeter of a permanent pool that is normally vegetated with aquatic plants to provide pollutant removal.

Aquifer
A porous water-bearing formation of permeable rock, sand or gravel capable of yielding economically significant quantities of groundwater.

Baseflow
The portion of streamflow that is not due to storm runoff but is the result of groundwater discharge or discharge from lakes or similar permanent impoundments of water.

Biochemical Oxygen Demand (BOD)
A measure of the quantity of organic material that can be decomposed through oxidation by micro-organisms.

Bioretention
A practice to manage and treat stormwater runoff by using a specially designed planting soil bed and planting materials to filter runoff stored in a shallow depression. The areas consist of a mix of elements each designed to perform different functions in the removal of pollutants and attenuation of stormwater runoff.

Building Setbacks
The distance between a structure and a property boundary (front, rear, or side) of the lot on which the structure is located.

Catch Basin Inserts
A structure, such as a tray, basket, or bag, that typically contains a pollutant removal medium (i.e., filter media) and a method for suspending the structure in the catch basin. They are placed directly inside of existing catch basins where stormwater flows into the catch basin and is treated as it passes through the structure.

Catch Basin
A structure placed below grade to conduct water from a street or other paved surface to the storm sewer.

Check Dams	Small temporary dams constructed across a swale or drainage ditch to reduce the velocity of concentrated stormwater flows.
Chemical Oxygen Demand (COD)	A measure of the amount of organic material that can be chemically oxidized.
Cisterns	Containers that store larger quantities of rooftop stormwater runoff and may be located above or below ground. Cisterns can also be used on residential, commercial, and industrial sites. See also Rain Barrel.
Coagulant	A chemical added to wastewater or stormwater that destabilizes the surface charge of fine particles, allowing the particles to come together to form larger particles that can be more easily removed by gravity settling and other physical treatment processes. Alum is a common coagulant used in lake management applications and sometimes used for stormwater treatment.
Coastal Area	As defined in CGS §22a-94(a), land and water within the towns listed in Table 1-2 of this Manual.
Coastal Boundary	As defined in CGS §22a-94(b), a region within the coastal area delineated by the contour elevation of the one hundred year frequency coastal flood zone, as defined and determined by the National Flood Insurance Act; or a one thousand foot linear setback measured from the mean high water mark in coastal waters; or a one thousand foot linear setback measured from the inland boundary of tidal wetlands mapped under C.G.S. §22a-20, whichever is farthest inland.
Combined Sewer Overflows (CSOs)	Combined sewers collect both stormwater runoff and sanitary wastewater in a single set of sewer pipes. When combined sewers do not have enough capacity to carry all the runoff and wastewater or the receiving water pollution control plant cannot accept all the combined flow, the combined wastewater overflows from the collection system into the nearest body of water, creating a CSO.
Darcy's Law	An equation stating that the rate of fluid flow through a porous medium is proportional to the potential energy gradient within the fluid. The constant of proportionality is the hydraulic conductivity, which is a property of both the porous medium and the fluid moving through the porous medium.
Deep Sump Catch Basins	Storm drain inlets that typically include a grate or curb inlet and a sump to capture trash, debris and some sediment and oil and grease. Also known as an oil and grease catch basin.
Deicers	Materials applied to reduce icing on paved surfaces. These consist of salts and other formulated materials that lower the melting point of ice, including sodium chloride, calcium chloride, calcium magnesium acetate, and blended products consisting of various combinations of sodium, calcium, magnesium, chloride, and other constituents.
Deicing Constituents	Additives included in deicing materials to prevent caking and inhibit corrosion.
Dissolved Pollutants	Non-particulate pollutants typically removed through removal mechanisms such as adsorption, biological uptake, chemical precipitation or ion exchange.

Downstream Analysis Calculation of peak flows, velocities, and hydraulic effects at critical downstream locations to ensure that proposed projects do not increase post-development peak flows and velocities at these locations.

Dry Detention Pond Stormwater basin designed to capture, temporarily hold, and gradually release a volume of stormwater runoff to attenuate and delay stormwater runoff peaks. Dry detention ponds provide water quantity control (peak flow control and stream channel protection) as opposed to water quality control. Also known as "dry ponds" or "detention basins".

Dry Well Small excavated pits or trenches filled with aggregate that receive clean stormwater runoff primarily from building rooftops. Dry wells function as infiltration systems to reduce the quantity of runoff from a site. The use of dry wells is applicable for small drainage areas with low sediment or pollutant loadings and where soils are sufficiently permeable to allow reasonable rates of infiltration.

Emergency Spillway Auxiliary outlet to a water impoundment that transmits floodwater exceeding the capacity of the primary spillway.

Erosion The wearing away of land surface by running water, wind, ice or other geological agents, including such processes as gravitational creep.

Erosion and Sediment Control A device placed, constructed on, or applied to the landscape that prevents or curbs the detachment of soil, its movement and/or deposition.

Failing Septic System An on-site wastewater disposal system that discharges effluent into the ground at concentrations that exceed water quality standards. Failing systems can be significant sources of nutrients, especially nitrogen, and microbial pathogens to both surface water and groundwater.

Filter Strip A strip or area of vegetation for removing sediment, organic material, nutrients and chemicals from runoff or wastewater. They are typically located downgradient of stormwater outfalls and level spreaders to reduce flow velocities and promote infiltration/filtration.

Filtering Practices Practices that capture and store stormwater runoff and pass it through a filtering media such as sand, organic material, or soil for pollutant removal. Stormwater filters are primarily water quality control devices designed to remove particulate pollutants and, to a lesser degree, bacteria and nutrients.

Floodplain Any land susceptible to being inundated by water, usually adjacent to a stream, river or water body and usually associated with a particular design flooding frequency (e.g., 100-year floodplain).

Flow Splitter An engineered, hydraulic structure designed to divert a percentage of stormwater to a treatment practice located outside of the primary channel or to direct stormwater to a parallel pipe system or to bypass a portion of baseflow around a treatment practice.

Fourth Order Stream Stream order indicates the relative size of a stream based on Strahler's (1957) method. Streams with no tributaries are first order streams, represented as the start of a solid line on a 1:24,000 USGS Quadrangle Sheet. A second order stream is formed at the confluence of two first order streams, and so on.

Fresh-tidal Wetland
A tidal wetland with an annual average salinity of less than 0.5 parts per thousand.

Full Sedimentation Design
Stormwater filter system design involving storage and pretreatment of the entire water quality volume.

Grass Drainage Channels
Traditional vegetated open channels, typically trapezoidal, triangular, or parabolic in shape, whose primary function is to provide non-erosive conveyance, typically up to the 10-year frequency design flow. They provide limited pollutant removal through filtration by grass or other vegetation, sedimentation, biological activity in the grass/soil media, as well as limited infiltration if underlying soils are pervious.

Groundwater Recharge
The process by which water that seeps into the ground, eventually replenishing groundwater aquifers and surface waters such as lakes, streams, and the oceans. This process helps maintain water flow in streams and wetlands and preserves water table levels that support drinking water supplies.

Groundwater Recharge Volume (GRV)
The post-development design recharge volume (i.e., on a storm event basis) required to minimize the loss of annual pre-development groundwater recharge. The GRV is determined as a function of annual pre-development recharge for site-specific soils or surficial materials, average annual rainfall volume, and amount of impervious cover on a site.

Heavy Metals
Metals such as copper, zinc, barium, cadmium, lead, and mercury, which are natural constituents of the Earth's crust. Heavy metals are stable and persistent environmental contaminants since they cannot be degraded or destroyed.

Hydraulic Conductivity
The rate at which water moves through a saturated porous media under a unit potential-energy gradient. It is a measure of the ease of water movement in soil and is a function of the fluid as well as the porous media through which the fluid is moving.

Hydraulic Head
The kinetic or potential energy of a unit weight of water expressed as the vertical height of water above a reference datum.

Hydrocarbons
Inorganic compounds consisting of carbon and hydrogen, including petroleum hydrocarbons derived from crude oil, natural gas, and coal.

Hydrodynamic Separators
A group of stormwater treatment technologies designed to remove large particle total suspended solids and large oil droplets, consisting primarily of cylindrical-shaped devices that are designed to fit in or adjacent to existing stormwater drainage systems. The most common mechanism used in these devices is vortex-enhanced sedimentation, where stormwater enters as tangential inlet flow into the side of the cylindrical structure. As the stormwater spirals through the chamber, the swirling motion causes the sediments to settle by gravity, removing them from the stormwater.

Hydrograph
A graph showing the variation in discharge or depth of a stream of water over time.

Hydrologic Cycle
The distribution and movement of water between the earth's atmosphere, land, and water bodies.

Hydrologic Zones
Planting zones that reflect the degree and duration of inundation by water, consisting of a deep water pool, shallow water bench, shoreline fringe, riparian fringe, floodplain terrace, and upland slopes.

Illicit Discharges
Unpermitted discharges to waters of the state that do not consist entirely of stormwater or uncontaminated groundwater except certain discharges identified in the DEP Phase II Stormwater General Permit.

Impaired Waters [303(d) List]
Those water bodies not meeting water quality standards. This list of impaired waters within each state is referred to as the "303(d) List" and is prepared pursuant to Section 303(d) of the Federal Clean Water Act.

Impervious Surfaces
Surfaces that cannot infiltrate rainfall, including rooftops, pavement, sidewalks, and driveways.

Infiltration Practices
Stormwater treatment practices designed to capture stormwater runoff and infiltrate it into the ground over a period of days, including infiltration trenches and infiltration basins.

Infiltration Rate
A soil characteristic determining or describing the maximum rate at which water can enter the soil under specific conditions.

Instantaneously Mixed Reservoir
A hypothetical model of a natural water body or impoundment in which the contents are sufficiently well-mixed as to be uniformly distributed.

Integrated Pest Management (IPM)
An approach to pesticide usage that combines monitoring; pest trapping; establishment of action thresholds; use of resistant varieties and cultivars; cultural, physical, and biological controls; and precise timing and application of pesticide treatments to avoid the use of chemical pesticides when possible and use the least toxic pesticide that targets the pest of concern, when pesticide usage is unavoidable.

Low Flow Orifice
Principal outlet of a stormwater treatment practice to convey flows above the permanent pool elevation.

Low Impact Development (LID)
Low impact development is a site design strategy intended to maintain or replicate predevelopment hydrology through the use of small-scale controls integrated throughout the site to manage runoff as close to its source as possible.

Media Filters
These devices consist of media, such as pleated fabric, activated charcoal, perlite, amended sand and perlite mixes, or zeolite placed within filter cartridges that are typically enclosed in concrete vaults. Stormwater is passed through the media, which traps particulates and/or soluble pollutants

Micropool
A smaller permanent pool that is incorporated into the design of a larger stormwater pond to avoid resuspension of particles.

Municipal Separate Storm Sewer System (MS4)
Conveyances for stormwater, including, but not limited to, roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels or storm drains owned or operated by any munici pality, sewer or sewage district, fire district, State agency or Federal agency and discharging directly to surface waters of the state.

Native Plants
Plants that are adapted to the local soil and rainfall conditions and that require minimal watering, fertilizer, and pesticide application.

Nitrate	One of the forms of nitrogen found in aquatic ecosystems. It is produced during nitrification and denitrification by bacteria. Nitrate is the most completely oxidized state of nitrogen commonly found in water, and is the most readily available state utilized for plant growth.
Nitrite	A form of nitrogen that is the end product of nitrification, which is produced by *Nitrobacter spp*. Nitrate is also the initial substrate for denitrification.
Nonpoint Source Pollution	Pollution caused by diffuse sources that are not regulated as point sources and are normally associated with precipitation and runoff from the land or percolation.
Non-Routine Maintenance	Corrective measures taken to repair or rehabilitate stormwater controls to proper working condition. Non-routine maintenance is performed as needed, typically in response to problems detected during routine maintenance and inspections.
Non-Structural Controls	Pollution control techniques, such as management actions and behavior modification that do not involve the construction or installation of devices.
Oil/Particle Separators	Consist of one or more chambers designed to remove trash and debris and to promote sedimentation of coarse materials and separation of free oil (as opposed to emulsified or dissolved oil) from stormwater runoff. Oil/particle separators are typically designed as off-line systems for pre-treatment of runoff from small impervious areas, and therefore provide minimal attenuation of flow. Also called oil/grit separators, water quality inlets, and oil/water separators.
Open Space Development	A compact form of development that concentrates density in one portion of the site in exchange for reduced density elsewhere. Also known as cluster or conservation development.
Optical Brighteners	Fluorescent white dyes that are additives in laundry soaps and detergents and are commonly found in domestic wastewater.
Partial Sedimentation Design	Stormwater filter system design involving storage and pretreatment of a portion of the water quality volume.
Peak Flow Control	Criteria intended to address increases in the frequency and magnitude of a range of potential flood conditions resulting from development and include stream channel protection, conveyance protection, peak runoff attenuation, and emergency outlet sizing.
Performance Monitoring	Collection of data on the effectiveness of individual stormwater treatment practices.
Permanent (Wet) Pool	An area of a detention basin or flood control project that has a fixed water surface elevation due to a manipulation of the outlet structure.
Permeable Paving Materials	Materials that are alternatives to conventional pavement surfaces and that are designed to increase infiltration and reduce stormwater runoff and pollutant loads. Alternative materials include modular concrete paving blocks, modular concrete or plastic lattice, cast-in-place concrete grids, and soil enhancement technologies. Stone, gravel, and other low-tech materials can also be used as alternatives for low traffic applications such as driveways, haul roads, and access roads.

Phase II Stormwater
The second phase of the NPDES program which specifically targets certain regulated small MS4s and construction activity disturbing between one and five acres of land.

Plug Flow
A hypothetical model of a natural water body or impoundment in which advection dominates (i.e., substances are discharged in the same sequence in which they enter).

Point Source
Any discernible, confined and discrete conveyance, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel or other floating craft from which pollutants are or may be discharged.

Porous Pavement
Porous pavement is similar to conventional asphalt or concrete but is formulated to have more void space for greater water passage through the material.

Pretreatment
Techniques used in stormwater management to provide storage and removal of coarse materials, floatables, or other pollutants before the primary treatment practice.

Primary Stormwater Treatment Practice
Stormwater treatment practices that are capable of providing high levels of water quality treatment as stand-alone devices; can be grouped into five major categories stormwater ponds, stormwater wetlands, infiltration practices, filtering practices, and water quality swales.

Principal Spillway
The primary pipe or weir that carries baseflow and storage flow through the embankment.

Quality Assurance Project Plan (QAPP)
A document describing the planning, implementation, and assessment procedures for a particular project, as well as any specific quality assurance and quality control activities. It integrates all the technical and quality assurance and control aspects of the project to provide a comprehensive plan for obtaining the type and quality of environmental data and information needed for a specific decision or use.

Rain Barrels
Barrels designed to retain small volumes of runoff for reuse for gardening and landscaping. They are applicable to residential, commercial, and industrial sites and can be incorporated into a site's landscaping plan. The size of the rain barrel is a function of rooftop surface area and the design storm to be stored.

Rain Garden
Functional landscape elements that combine plantings in depressions that allow water to pool for only a few days after a rainfall then be slowly absorbed by the soil and plantings.

Rainwater Harvesting
The collection and conveyance of rainwater from roofs and storage in either rain barrels or cisterns. Depending on the type and reuse of the rainwater, purification may be required prior to distribution of the rainwater for reuse. Harvested rainwater can be used to supply water for drinking, washing, irrigation, and landscaping.

Rational Equation
An equation that may be appropriate for estimating peak flows for small urbanized drainage areas with short times of concentration, but does not estimate runoff volume and is based on many restrictive assumptions regarding the intensity, duration, and aerial coverage of precipitation.

Retention (or Residence) Time — The average length of time that a “parcel” of water spends in a stormwater pond or other water body.

Riser — A vertical pipe extending from the bottom of a pond that is used to control the discharge rate for a specified design storm.

Routine Maintenance — Maintenance performed on a regular basis to maintain proper operation and aesthetics.

Runoff Capture Volume (RCV) — The runoff capture volume is equivalent to the water quality volume (WQV) and is the stormwater runoff volume generated by the first inch of rainfall on the site.

Safety Bench — A flat area above the permanent pool and surrounding a stormwater pond or wetland to provide separation from the pool and adjacent slopes.

Seasonally High Groundwater Table — The highest elevation of the groundwater table typically observed during the year.

Secondary Stormwater Treatment Practices — Stormwater treatment practices that may not be suitable as stand-alone treatment because they either are not capable of meeting the water quality treatment performance criteria or have not yet received the thorough evaluation needed to demonstrate the capabilities for meeting the performance criteria.

Sediment Chamber or Forebay — A underground chamber or surface impoundment (i.e., forebay) designed to remove sediment and/or floatables prior to a primary or other secondary stormwater treatment practice.

Sensitive Watercourse — Streams, brooks, and rivers that are classified by DEP as Class A (fishable, swimmable, and potential drinking water), as well as their tributary watercourses and wetlands, that are high quality resources that warrant a high degree of protection.

Shallow Marsh — The portion of a stormwater wetland that consists of aquatic vegetation within a permanent pool ranging in depth from 6” to 18” during normal conditions.

Shared Parking — A strategy that reduces the number of parking spaces needed by allowing adjacent land uses with different peak parking demands to share parking lots.

Site Planning and Design — Techniques of engineering and landscape design that maintaining predevelopment hydrologic functions and pollutant removal mechanisms to the extent practical.

Site Stormwater Management Plan — Plan describing the potential water quality and quantity impacts associated with a development project both during and after construction. It also identifies selected source controls and treatment practices to address those potential impacts, the engineering design of the treatment practices, and maintenance requirements for proper performance of the selected practices.

Soil Infiltration Capacity — The maximum rate at which water can infiltrate into the soil from the surface.

Soluble Phosphorus
Soluble phosphorus is present predominantly as the ionic species orthophosphate and is thought to be the form readily taken up by plants, i.e., “bioavailable.”

Source Controls
Practices to limit the generation of stormwater pollutants at their source.

Stormwater
Water consisting of precipitation runoff or snowmelt.

Stormwater Hotspots
Land uses or activities with potential for higher pollutant loads.

Stormwater Pollution Prevention Plan (SWPPP)
Identifies potential sources of pollution and outlines specific management activities designed to minimize the introduction of pollutants into stormwater.

Stormwater Ponds
Vegetated ponds that retain a permanent pool of water and are constructed to provide both treatment and attenuation of stormwater flows.

Stormwater Retrofits
Modifications to existing development to incorporate source controls and structural stormwater treatment practices to remedy problems associated with, and improve water quality mitigation functions of, older, poorly designed, or poorly maintained stormwater management systems.

Stormwater Treatment Practices
Devices constructed for primary treatment, pretreatment or supplemental treatment of stormwater.

Stormwater Treatment Train
Stormwater treatment practices, as well as site planning techniques and source controls, combined in series to enhance pollutant removal or achieve multiple stormwater objectives.

Stormwater Wetlands
Shallow, constructed pools that capture stormwater and allow for the growth of characteristic wetland vegetation.

Street Sweepers
Equipment to remove particulate debris from roadways and parking lots, including mechanical broom sweepers, vacuum sweepers, regenerative air sweepers and dry vacuum sweepers.

Structural Controls
Devices constructed for temporary storage and treatment of stormwater runoff.

Submerged Aquatic Vegetation (SAV)
Includes rooted, vascular, flowering plants that live permanently submerged below the water in coastal, tidal and navigable waters.

Synthetic Organic Chemicals
Chemicals that contain carbon, but are not naturally occurring.

Technology Acceptance and Reciprocity Partnership (TARP)
TARP was formed by the states of California, Illinois, Maryland, Massachusetts, New Jersey, New York, Pennsylvania, and Virginia to development standard protocols for the collection and evaluation of performance data for new environmental technologies.

Tidal Wetland
As defined in CGS §22a-29(2), those areas that border on or lie beneath tidal waters whose surface is at or below an elevation of one foot above local extreme high water and upon which may grow or be capable of growing some, but not necessarily all, of a list of specific plant species.

Time of Concentration
The time required for water to flow from the most distant point to the downstream outlet of a site. Runoff flow paths, ground surface slope and roughness, and channel characteristics affect the time of concentration.

Total Kjeldahl Nitrogen (TKN)	The sum of the ammonia nitrogen and the organic bounded nitrogen; nitrates and nitrites are not included.
Total Maximum Daily Load (TMDL)	A calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources, including a margin of safety.
Total Nitrogen	The sum of total Kjeldahl nitrogen, nitrate, and nitrite. Nitrogen is typically the growth-limiting nutrient is estuarine and marine systems.
Total Organic Carbon	A measure of the organic matter content. The amount of organic matter content affects biogeochemical processes, nutrient cycling, biological availability, chemical transport and interactions and also has direct implications in the planning of wastewater treatment and drinking water treatment.
Total Phosphorus	Sum of orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate. Phosphorus is typically the growth-limiting nutrient is freshwater systems.
Total Suspended Solids	The total amount of particulate matter that is suspended in the water column.
Technical Release Number 55 (TR-55)	A watershed hydrology model developed by the Soil Conservation Service (now Natural Resources Conservation Service) used to calculate runoff volumes, peak flows, and simplified routing for storm events through ponds.
Trash Rack	A structural device (e.g., screen or grate) used to prevent debris from entering a spillway, channel, drain, pump or other hydraulic structure.
Underground Detention Facilities	Vaults, pipes, tanks, and other subsurface structures designed to temporarily store stormwater runoff for water quantity control and to drain completely between runoff events. They are intended to control peak flows, limit downstream flooding, and provide some channel protection.
Underground Infiltration Systems	Structures designed to capture, temporarily store, and infiltrate the water quality volume over several days, including premanufactured pipes, vaults, and modular structures. Used as alternatives to infiltration trenches and basins for space-limited sites and stormwater retrofit applications.
Urban Stormwater Runoff	Stormwater runoff from developed areas.
Vegetated Buffer	An area or strip of land in permanent undisturbed vegetation adjacent to a water body or other resource that is designed to protect resources from adjacent development during construction and after development by filtering pollutants in runoff, protecting water quality and temperature, providing wildlife habitat, screening structures and enhancing aesthetics, and providing access for recreation.
Vegetated Filter Strips and Level Spreaders	Uniformly graded vegetated surfaces (i.e., grass or close-growing native vegetation) located between pollutant source areas and downstream receiving waters or wetlands. A level spreader is usually located at the top of the slope to distribute overland flow or concentrated runoff (see the maximum overland flow length guidelines above) evenly across the entire length of the filter strip.

Vegetated Roof Covers

Multilayered, constructed roof systems consisting of a vegetative layer, media, a geotextile layer, and a synthetic drain layer installed on building rooftops. Rainwater is either intercepted by vegetation and evaporated to the atmosphere or retained in the substrate before being returned to the atmosphere through transpiration and evaporation. Also referred to as green roofs.

Water Balance

Equation describing the input, output, and storage of water in a watershed or other hydrologic system.

Water Quality Flow (WQF)

The peak flow associated with the water quality volume calculated using the NRCS Graphical Peak Discharge Method.

Water Quality Swales

Vegetated open channels designed to treat and attenuate the water quality volume and convey excess stormwater runoff. Dry swales are primarily designed to receive drainage from small impervious areas and rural roads. Wet swales are primarily used for highway runoff, small parking lots, rooftops, and pervious areas.

Water Quality Volume (WQV)

The volume of runoff generated by one inch of rainfall on a site.

Watershed Management

Integrated approach addressing all aspects of water quality and related natural resource management, including pollution prevention and source control.

Xeriscaping

Landscaping to minimize water usage ("xeri" is the Greek prefix meaning "dry") by using plants that are adapted to the local climate and require minimal watering, fertilizer, and pesticide application, and improving soils by adding soil amendments or using mulches to reduce the need for watering by increasing the moisture retained in the soil.