STORM WATER MANAGEMENT PROGRAM PLAN

FOR

THE HURON-CLINTON METROPOLITAN AUTHORITY

Public Education Plan
December 21. 2004
Illicit Discharge Elimination Plan
August 1, 2004
Public Involvement and Participation
Post Construction Storm Water Management
Construction Storm Water Runoff
Pollution Prevention
November 31, 2005

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MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
(MICHIGAN DEPARTMENT OF NATURAL RESOURCES & ENVIRONMENT)

PHASE II STORM WATER REGULATIONS

GENERAL STORM WATER PERMIT
MIS049000

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GENERAL INFORMATION

The Huron-Clinton Metropolitan Authority is a regional park authority serving Livingston, Macomb, Oakland, Washtenaw and Wayne Counties. It was sanctioned by the Michigan State Legislature in Act No. 147 of Public Acts of 1939, and was approved in 1940 by the citizens of the five counties which constitute the metropolitan district. The governing body of the Authority is a seven member Board of Commissioners. Two Commissioners are appointed by the Governor of Michigan and five Commissioners, one each to represent each member county, are appointed by the Board of Commissioners of each member county.

Named after the two longest rivers within its boundaries, the Authorities main endeavor is to provide a variety of recreational opportunities through the development of parks and open spaces along the Huron and Clinton rivers for the benefit of the citizens of Southeastern Michigan. Since its inception, the Authority has created thirteen Metroparks covering nearly 25,000 acres within the five counties. These 13 Metroparks have an annual visitation of approximately 9.3 million people per year. Nearly 80% of the total HCMA land holdings, or approximately 20,000 acres is left in a natural state. 3,500 acres are developed for recreation, interpretation or other public uses, and an additional 1,400 acres is open space or leased to local municipalities.

NESTED JURISDICTIONS

HCMA believes there are no other public entities with regulated separate storm sewer systems within the HCMA jurisdictional boundaries.

STORM WATER PROGRAM MANAGER

Michael Arens, Chief Engineer has been appointed as Storm Water Program Manager for the HCMA and is responsible for implementation of the plan and compliance with the General Permit and COC.

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PLAN OBJECTIVES

This document describes the Huron-Clinton Metropolitan Authority (Metroparks) plan to implement a storm water management program to reduce the discharge of pollutants to the Waters of the State within its jurisdiction. This plan has been developed to fulfill the requirements for Part I. Section B of the State of Michigan's National Pollutant Discharge Elimination System (NPDES) General Permit (MIS049000) for Storm Water Discharges from Separate Storm Water Drainage Systems (MS4s). Although it operates under a Jurisdictional Permit, the HCMA has been participating in the watershed planning process with the Stony/Paint Creek, Lower Huron and Kent Lake Sub-watershed Groups. The Metroparks has property within both the Huron and Clinton River Watersheds and the Storm Water Management Program Plan (SWMPP) will be implemented within the requested area of coverage as determined by the urbanized areas outlined in the General Permit.

The purpose of the SWMPP is to develop a program to implement the six minimum measures as required by the General Permit which include the Public Information Plan (PEP), the Public Involvement and Participation Plan (PIP), the Illicit Discharge Elimination Plan (IDEP), the Post Construction Storm Water

Management Program for New Development and Redevelopment Projects**,** Construction Storm Water Runoff Control and Pollution Prevention / Good Housekeeping for Municipal Operations all of which are designed to minimize the negative impacts or reduce discharge of pollutants within the storm water conveyances of the Metroparks to the Maximum Extent Possible (MEP). The MEP requirement will be met by:

1) Educating the public, HCMA employees and its vendors on potential negative impacts of storm water discharge on receiving waters;
2) Training appropriate HCMA staff on the investigation of illicit connections and discharges, including those from on-site disposal systems (OSDS) with emphasis on outfall observations/screenings, safety issues and natural occurring phenomenon;
3) Implementing a system for identifying and eliminating illicit discharges and connections to the MS4s including outfall observations and follow-up sampling;
4) Locating and accurately mapping the storm water conveyances and outfalls owned and operated by the HCMA within the requested area of coverage,
5) Determining the ownership of other significant storm water conveyances in the HCMA and initiate a process to bring any “orphan” drains under proper jurisdiction;
6) Working with the Drain Commissioner and County Department of Public Health in their efforts to develop and implement an OSDS inspection program and;
7) Coordinating HCMA IDEP efforts with other local communities and impacted County agencies;
8) The identification and implementation of Best Management Practices (BMPs) to comply with the minimum measures of Part 1., including cooperation with other permittees as necessary to assure compliance;
9) The identification and implementation of BMPs to comply with storm water related requirements established in a corrective action plan to meet TMDLs as applicable;
10) Demonstration of effectiveness or environmental benefit of the program

PLAN IMPLEMENTATION

The following section summarizes the required elements of the SWMPP as specified in Part I of the MDEQ General Storm Water Permit (MIS049000) and the Metroparks plans for addressing each element. The Metroparks are committed to implementing the program and to completing activities to meet each of the required elements within the appropriate time frame. The actions completed will comply with the regulations and meet plan objectives. The Metroparks will prepare a report as required by the COC to the MDNRE and advise them of any changes in the plan.

Public Education Plan

December 21, 2004, Updated July 2008, February 2010

INTRODUCTION

As a requirement of the NPDES Phase II storm water permit, this Public Education Plan (PEP) was developed to inform both employees and visiting public of the Huron-Clinton Metroparks (HCMA) about their role in protecting water quality and preventing storm water pollution in their community. The PEP outlines education goals and messages that must be communicated under the requirements of the Phase II regulations. The PEP then describes the existing and future efforts the HCMA will undertake to achieve these education goals, and how these efforts will be evaluated.

The HCMA education efforts will be directed in two areas. The first will be employee education on items such as proper maintenance techniques, waste disposal, stewardship activities, etc., and the second area of education efforts will be directed toward park visitors and assisting surrounding communities with their watershed based educational programs through programs and events at the various Metropark nature interpretive centers. The HCMA has had a long history of educating the public on the natural resources of southeast Michigan, including water resource management, through its interpretive programs and nature center activities. It has had a longstanding involvement with both the Clinton and Huron River Watershed Council activities and has taken a leadership role in environmental initiatives such as the Michigan Turfgrass Environmental Stewardship Program and the Water Resources Stewardship Program

REQUIRED PUBLIC EDUCATION PLAN ELEMENTS

As indicated in Part I, Section A.5 of the State of Michigan NPDES General Permit (MIS049000), the primary goal of this PEP is to promote, publicize and facilitate education for encouraging the public and HCMA employees to reduce discharge of pollutants in storm water to the maximum extent practicable. This educational programming shall include:

A. Educating the public and HCMA employees on potential impacts on receiving waters including:

1) Hazards associated with illicit discharges and improper waste disposal.
2) The identification of impacted water bodies
3) The location of waste disposal sites
4) Acceptable application and disposal of pesticides, herbicides and fertilizers.
5) Proper vehicle cleaning procedures
6) Septic system maintenance
7) Riparian management techniques
8) Public responsibility for stewardship
9) The use of native vegetation
10) Educate HCMA vendors and HCMA employees involved with food service regarding the elimination of grease and litter discharges to storm drains.

Although it has applied for a Jurisdictional Permit, the HCMA has been participating in the watershed planning process with the Stony/Paint Creek, Lower Huron and Kent Lake Sub-watershed Groups. The HCMA has property within both the Huron and Clinton River Watersheds and the PEP will be implemented organization wide.

EXISTING AND PROPOSED PUBLIC EDUCATION ACTIVITIES

This section details the existing educational activities in place within the Huron-Clinton Metropark system as well as proposed educational activities designed to encourage the public and HCMA employees to reduce the discharge of pollutants into storm water. Proposed activities are or will be completed with the involvement of additional parties as noted in each BMP activity description, or in cooperation with other Phase II communities.

This Public Education Plan (PEP) was updated from the original PEP which was developed by discussions with: HCMA Engineering, HCMA Planning, HCMA Interpretive Services, HCMA Food Services, Clinton River Watershed Council, Huron River Watershed Council, SEMCOG, MSU Extension and various County and municipal representatives.

The following paragraphs summarize elements specified in the MDEQ General Storm water Permit and the plan for addressing each.

> A. Educating the public and HCMA employees on potential impacts on receiving waters including: Hazards associated with illicit discharges and improper waste disposal; the identification of impacted water bodies; the location of waste disposal sites; acceptable application and disposal of pesticides, herbicides and fertilizers; proper vehicle cleaning procedures; septic system maintenance; riparian management techniques; public responsibility for stewardship; use of native vegetation; and grease and litter discharges.

This SWMP shall target visitors, public, employees, vendors & construction contractors.

EXISTING EFFORTS:

<u>General Maintenance Practices / Proper Use of Fertilizers & Pesticides</u>

Target audience: Golf Course Management Staff

Message content: The HCMA has been involved in the Michigan Turfgrass Environmental Stewardship Program (MTESP) since its' inception in 1998. Nine Metropark golf courses are fully MTESP Certified with Kensington Metropark Golf Course being the first in the State to achieve such Certification. To remain certified, property owners must continue with stated Best Management Practices, educational opportunities, regulation updates and participate in a program review every 3rd year.

The Michigan Turfgrass Environmental Stewardship Program is dedicated to protecting ground and surface water resources by advancing turfgrass management programs, developing pollution prevention techniques and promoting the understanding and compliance of state environmental laws and regulations. This program is a cooperative partnership between Michigan State University, Michigan Department of Agriculture, Michigan Department of Environmental Quality, Golf Association of Michigan and the Michigan Turfgrass Foundation. The program focuses on education and assistance to the golf industry to assure compliance of state regulations including pesticide& fertilizer handling and storage, wellhead protection, fuel storage, enhancing and protection of wildlife habitat and protection of the states water resources.

Target audience: Grounds Management Staff

Message content: Each year through educational seminars and conferences, HCMA employees increase their knowledge of Best Management Practices, Integrated Pest Management and issues relating to the environment and grounds maintenance practices including management decisions effecting water resources. Every year, employees attended classes at the Michigan Forestry and Parks Assoc Conference, the Great Lakes Park Training Institute and the Michigan Turfgrass Foundation Conference, to name a few. As an example, the Michigan Turfgrass Conference is a four day event held in Lansing, Michigan in January, and is considered one of the premier national turfgrass educational events of the year. Industry educators, researchers and speakers from throughout the country report on turfgrass research and field experience. The Michigan Turfgrass Foundation Field Day is held in August each year. This educational Field Day allows MSU professors and Graduate Students to show and demonstrate their research at the Hancock Turfgrass Research Center. This is an opportunity to get "up-close and personal" with the latest research being conducted at Michigan State University and to have the opportunity to ask questions of the experts.

Each year the HCMA sends over 60 employees to these educational sessions to keep up to date on fertilizer and pesticide use, turfgrass Best Management Practices, water use issues and other environment initiatives. HCMA is committed to having a well educated workforce in order to promote sound management decisions in the field.

The HCMA also makes pesticide certification training available to all maintenance employees and a mandatory requirement of any supervisory personnel. Over 50 employees currently hold a MDA pesticide certification in multiple categories. This certification helps to insure that employees are kept up to date with current pesticide use techniques, laws and regulation, as well as proper spill prevention and emergency response techniques.

Timetable: Throughout the permit cycle.

Responsible party for implementation: Golf Course Supervisors

Evaluation mechanism: Number of Employees Involved in Training

<u>Storm Water Management / Native Vegetation</u>

Target audience: Planning, Engineering, and Natural Resource Staff

Message content The HCMA professional staff continues to keep up to date with latest information on erosion control, storm water management and use of native plant material through professional development courses, seminars, workshops and literature. HCMA staff are involved in and hold membership to and/or are committee members of various resource related organizations including but not limited to the Michigan Stewardship Network, the Oakland County Natural Areas Advisory Group, the Michigan Turfgrass Foundation, the Michigan Turfgrass Environmental Stewardship Program, SEMCOG Environmental Policy Advisory Committee and the Oakland County Water Resources Stewardship Program. HCMA also has personal that are certified storm water management officers.

Target audience: Visitors, students, educators, public employees, public officials, construction contractors

Message content: The HCMA has developed an environmental education facility at Indian Springs Metropark, located in Springfield Township, Oakland County, Michigan. The Indian Springs Environmental Discovery Center (EDC) occupy a 90-acre site within the 2,200 acre park.

The EDC offers a broad range of nature interpretation, environmental demonstration, recreational opportunities and conference facilities to a variety of user groups, focusing primarily on youth and families. Principal themes include native ecosystem restoration, botanical demonstrations, resource conservation, water resource management and protection, and sustainable development.

The EDC provides educational programs that enhance environmental learning opportunities for schools in the five-county Metropark region of Oakland, Wayne, Macomb, Livingston and Washtenaw counties as well as the general public. The program takes advantage of the unique features at Indian Springs: its ecosystem restorations, its proximity to the headwaters of the Huron River, and well-equipped facilities. Restored and created emergent wetlands, fens, prairies, forests and their associated wildlife inhabitants are within arm's reach for visitors, and a mouse-click away for the rest of the world. Digital technology bring interactive nature programs and wildlife action into the classroom in real-time.

As an environmental education center, the HCMA is striving to promote and illustrate best management practices for storm water treatment and the use of native vegetation in the landscape. Over 60 acres of the site is planted in native grasses and forbs, including the parking lot where all of the storm water is captured in vegetative swales planted with native grasses. Excess water that is not assimilated into the swale soil is sent to an adjacent retention pond to evaporate or in the event of heavy rain, flow out through a piped diffuser system into the ground. As the system is designed, the storm water is intended to outlet along the diffuser pipe and use the natural drainage properties of the native soils to disperse. The goal of the EDC design is to have no storm water leave the site. These facilities are available to the general public, public officials, students and educators on a year-round basis as examples of storm water management and the use of native plants in the landscape.

Timetable: Throughout the permit cycle

Responsible party for implementation: HCMA operations

Evaluation mechanism: Number of visitors

<u>Southeast Michigan Partners for Clean Water Informational Materials</u>

Target audiences: Visitors, public employees, construction contractors.

Message content: Brochures, tip cards, posters, and other materials developed by the regional public outreach campaign, "Our water. Our future. Ours to Protect", are utilized. These materials contain information that covers all the key messages. The overall campaign promotes the Seven Simple Steps to Clean Water. Topics include: fertilizer, car care, landscaping, storm drain awareness, household hazardous wastes, water conservation, pet care, riparian protection. The campaign materials are distributed at municipal offices, events, web site, and direct mail.

Timetable: Throughout the permit cycle.

Responsible party for implementation: HCMA will ensure distribution of these materials to the appropriate target audiences. SEMCOG will develop the materials.

Evaluation mechanism: Number of materials distributed.

<u>Articles in HCMA Newsletter</u>

Target audiences: Residents, visitors, public employees, businesses, industries, construction contractors and developers

Message content: HCMA will continue to insert articles into existing distribution mechanisms such as the HCMA quarterly newsletter and website to meet the key messages.
Key messages include Southeast Michigan Partner's for Clean Water "Our water. Our future. Ours to protect."

Timetable: These articles will continue throughout the permit cycle on a quarterly basis.

Responsible party for implementation: HCMA Communications Department

Evaluation mechanism: Number of newsletters distributed.

Web Site Information

Target audiences:	Residents, visitors, public employees, businesses, industries, construction contractors and developers
Message content:	HCMA has added information to the HCMA web site and/or link to the "Our Water. Our future. Ours to protect." web site. Information will be included on watersheds, stewardship activities and events, and individual actions the public can take to protect water resources.
Timetable:	Web site links and information will continue through the permit cycle.
Responsible party for implementation:	HCMA will provide content and/or link to the SEMCOG , "Our Water. Our future. Ours to protect." web site.
Evaluation mechanism:	Number of hits

Water Quality Display

Target Audiences:	Visitors, public employees, & construction contractors.
Message content:	HCMA will utilize in-house displays or displays from other organizations such as the *"Our Water. Our Future. Ours to Protect."* table-top exhibit from SEMCOG for display at public events and HCMA facilities. This exhibit promotes watershed awareness with a map of southeast Michigan watersheds and community boundaries, explains how storm drains connect to our rivers and streams, and provides tips on what individuals can do to protect our water resources.
Timetable:	Displays will be set up at various times throughout the permit period
Responsible party for implementation:	HCMA will ensure that the displays are utilized at events and HCMA facilities throughout the permit period.
Evaluation mechanism:	Number of people visiting the display. Number of events. Estimates of event attendance.

River Day Activities

Target Audiences:	Residents, visitors, public employees, businesses, industries, construction contractors and developers.
Message Content:	River day is an annual event promoting celebrations and stewardship of the water resource. HCMA will promote River Day activities through web site, newsletter, nature centers and possible sponsoring of a site/event.
Timetable:	Annual event held in June.
Responsible party for implementation:	HCMA Communications Department
Evaluation mechanism:	Number of participants, project results (varies by event).

Nature Interpretive Programs & Activities

Target Audiences:	Residents, visitors
Message Content:	HCMA will sponsor, promote and conduct water related nature interpretive programs at various Metroparks. Possible programs and events could include basics on watersheds and relating it to everyday activities in the watershed., lawn care, managing shoreline properties, landscaping shorelines with native vegetation, urban impacts on water resources, stewardship opportunities and disposal of hazardous materials. Educational materials could also be distributed on the "Island Queen II", excursion boat run by HCMA, which is a 49 passenger pontoon boat that tours the lake. The Interpretive Services Department has planned, programs identifying and measuring parameters used in gauging water quality. Students will learn how the analyze these parameters to determine the health and quality of a water body.

Timetable: Throughout the permit cycle
Responsible party for implementation: HCMA Department of Interpretive Services
Evaluation mechanism: Number of participants in nature programs

Signage at Road/Stream Crossings or Entering the Watershed

Target Audiences: Residents, visitors, public employees, businesses, industries, construction contractors and developers.

Message Content: Signage will contain messages that identify the watershed, tributary and the stewardship message, "Ours to Protect". Consistent signage has been developed as part of the Southeast Michigan Partners for Clean Water.
Timetable: Throughout the permit cycle
Responsible party for implementation: HCMA will coordinate with watershed councils for ordering the signs.
Evaluation mechanism: Number of signs installed.

Hazardous Waste / Yard Waste Collection / Reduction
Target audiences: HCMA Employees
Message content: HCMA will continue to educate employees on the proper handling and disposal of hazardous waste, pesticides, fertilizers, motor vehicle fluids and yard waste. HCMA will continue to be involved in the Clean Sweep Program for disposal of hazardous waste.
Timetable: On-going program.
Responsible party for implementation: HCMA Purchasing/Operations
Evaluation mechanism: Number of employees trained.

Educate commercial food service entities to prevent grease and litter discharges to storm drains.

Overall target audiences: Vendors and employees involved in food service within the park system.

Message Content: HCMA will conduct food service related programs at various Metroparks regarding the proper waste disposal practices in general and focusing on the proper disposal of greases and oils generated in the food service process or maintenance of food service equipment. Educational materials could also be distributed at this time and at other related programs as well as visual aids being posted in the work place.

Timetable: Throughout the permit cycle
Responsible party for implementation: HCMA Food Service Administrator/Operations
Evaluation mechanism: Number of programs/ number trained

Other Involved Organizations
In implementing this PEP, HCMA will pursue cooperative partnerships plus information and resource sharing with several organizations, including:

Organization	Program	Contact
SEMCOG	Ours to Protect campaign materials, mass media, Headwaters video, display, survey	Amy Mangus
MDNRE	Pollution prevention programs	
Clinton River Watershed Council	Adopt-A-Stream, River Day	Executive Director
Huron River Watershed Council	Adopt-A-Stream, River Day	Executive Director
MSU Extension	Water resource protection workshops, Managing Shoreline Property to Protect Water Quality Booklet	County Extension Agent
County Drain Commission	Use materials developed by the various drain commissions in interpretive programs.	Drain Commissioner

Public Involvement and Participation

Updated July 2008, February 2010

For any public agency, public involvement and participation is critical for responsible decision making. As a regional park system, the Metroparks does not have a residential or commercial constituency as is normally associated with a municipality or county government, but rather serves the residents of the five county region on a day use basis, which is approximately 10 million visitations per year. This unique situation offers the park system an opportunity for public participation and education from an alternative source that is intended to enhance the programs facilitated by the municipalities and communities in which the Metroparks are embedded. It is also an opportunity to address the issues on a regional level, extending beyond municipal and watershed borders.

The Metroparks has and will continue to maintain open lines of communication with the public that it serves in southeast Michigan. The following activities will be utilized as both solicitation and communication mechanisms for public involvement.

1) Monthly Public Meetings
2) Quarterly Newsletter
3) Web Site
4) Public Survey
5) Media / Press Release

PUBLIC MEETINGS:

The Board of Commissioners of the Huron-Clinton Metropolitan Authority conducts a regularly scheduled public meeting each month to discuss and make decisions regarding a variety of issues effecting management of the Metroparks. Storm water management is one of the issues that staff periodically bring before the Board and attending public. These meetings provide the public an opportunity to express their views on any issue including storm water management. If considered necessary, Metroparks staff will schedule additional public meetings to ensure that there is adequate time allowed for full and complete public participation in storm water issues effecting local communities. Metroparks staff will continue to attend and participate in Public Information meetings held by various sub watershed planning groups. In this way the Metroparks have been available to receive feedback from both the residents and public officials of participating municipalities. The Metroparks will continue to cooperate and participate in the watershed planning process with the organizations throughout the Phase II regulation implementation process.

NEWSLETTER:

Every quarter the HCMA prepares and distributes 33000 newsletters to the residents of southeast Michigan. These newsletters are used to inform the public about the storm water management planning process, incorporation of Public Education Plan goals on storm water management issues, and describe how to contact this organization for feedback regarding these issues.

WEB SITE:

The Metroparks website averages 4.2 million hits on a monthly basis. Metroparks patrons are familiar with using the website to gain access to all types of the information regarding the Metroparks facilities and activities. A section of this website is available for storm water management issues, information and pertinent internet links to help educate the public. From this web site, the public have an opportunity to submit questions and comments via e-mail.

PUBLIC SURVEY:

Every four years the Metroparks conducts and extensive public survey of people within the five county area, the results of which are used in developing the Metroparks Five Year Recreation Plan. This survey will be conducted in 2010 and will contain questions that will access the public perception and awareness of storm water pollution issues, their willingness to protect water resources and mechanisms to best receive storm water related information. The format of the survey will most likely be via phone, mail and/or direct contact with the park patron.

MEDIA / PRESS RELEASE:

When appropriate, the Metroparks Information and Public Relations Department provide information to the various media outlets pertaining to storm water management issues, public education opportunities, public involvement in storm water planning issues and any major findings with storm water issues. Press releases typically go to newspapers, radio and television outlets.

The Metroparks will follow required public notification requirements of this storm water management plan and the plan will be available for inspection at the Huron-Clinton Metropolitan Authority Administrative Offices daily from 8 a.m. to 4 p.m. The plan is available for viewing on the Metroparks website, www.metroparks.com.

WATERSHED COOPERATION:

Throughout the entire process, the Metroparks has been cooperating with other local units of government as well as both the Stony Creek and Huron River Watershed Councils in the development of watershed based storm water management plans. Although it is covered under a Jurisdictional Permit, the Metroparks participated in this watershed planning process with the Stony/Paint Creek, Lower Huron and Kent Lake Sub-watershed Groups. In a cooperative effort, The Metroparks attends and actively participates in citizen advisory meetings, public participation and information meetings and workshops. The Metroparks, as a major land holder in both the Clinton and Huron River watersheds, provided information to these organizations and local units of government and will continue to provide educational opportunities for various storm water management initiatives as well as provide examples of innovative storm water management projects for public viewing.

Illicit Discharge Elimination Plan

August 1, 2004, Updated July 2008, February 2010

IDEP Plan Objectives

This document describes the Huron-Clinton Metropolitan Authority (HCMA) plan for identifying and eliminating illicit connections and discharges to the Waters of the State within its jurisdiction. This plan has been developed to fulfill the requirements for Part I. Section A.7.of the State of Michigan's National Pollutant Discharge Elimination System (NPDES) General Permit (MIS049000) for Storm Water Discharges from Separate Storm Water Drainage Systems (MS4s). Although it is covered under a Jurisdictional Permit, the HCMA has been participating in the watershed planning process with the Stony/Paint Creek, Lower Huron and Kent Lake Sub-watershed Groups. The HCMA has property within both the Huron and Clinton River Watersheds and the IDEP is implemented within the requested area of coverage as determined by the urbanized areas outlined in the General Permit.

The purpose of the IDEP is to prohibit and effectively eliminate illicit discharges and connections to storm water conveyances within the HCMA. The Federal Phase II storm water regulations define "illicit discharge" and "illicit connection" as follows:

> Illicit discharge – Any discharge (or seepage) to the MS4 that is not composed entirely of storm water or uncontaminated groundwater. Examples of illicit discharges include, but are not limited to, the dumping of motor vehicle fluids, household hazardous wastes, grass clippings, leaf litter, or domestic animal wastes, or unauthorized discharge of sewage, industrial waste, restaurant wastes, or any other non-storm water waste into an MS4.
>
> Illicit connection – Means a physical connection to the MS4 that 1) primarily conveys illicit discharges into the MS4, or 2) is not authorized or permitted by the local authority (where a local authority requires such authorization or permit).

The HCMA has MS4s under its jurisdiction and as such, the objectives of this IDEP are to:

1) train appropriate HCMA staff on the investigation of illicit connections and discharges, including those from on-site disposal systems (OSDS) with emphasis on outfall observations/screenings, safety issues and natural occurring phenomenon,
2) implement a system for identifying and eliminating illicit discharges and connections to the MS4s including outfall observations and follow-up sampling,
3) locate and accurately map the storm water conveyances and outfalls owned and operated by the HCMA within the requested area of coverage,
4) determine the ownership of other significant storm water conveyances in the HCMA and initiate a process to bring any "orphan" drains under proper jurisdiction,
5) work with the Drain Commissioner and County Department of Public Health in their efforts to develop and implement an OSDS inspection program and,
6) coordinate HCMA IDEP efforts with other local communities and impacted County agencies.

Storm Water Drainage and Sanitary Waste Disposal

All of the land within the HCMA is used for recreational purposes or undeveloped open space. About 35% of the HCMA facilities are being served by on-site sewage disposal systems (OSDS).

The HCMA has separate sanitary and storm drainage systems under its jurisdiction. Appendix D, located at the end of this plan lists locations of known storm sewer outfalls and their receiving conveyance. The information presented is based on the HCMA records of as-built storm sewer, site plans and dry weather inspections. The HCMA currently knows of 54 outfalls under their jurisdiction within the urbanized areas of the 5 parks covered under the permit. They ultimately discharge to various receiving sites including the Black Creek Canal at Metro Beach, Macomb County, the Stony Creek and Stony Creek Impoundment at Stony Creek Metropark, Macomb County Kent Lake at Kensington Metropark, Oakland County, the McBride Drain and Huron River at Lower Huron Metropark, Wayne County, and Maltby Lake and associated wetlands at Huron Meadows Metropark in Livingston County.

PLANNED EFFORTS

The following subsections summarize the required elements of an IDEP as specified in Part I, Section A.7. of the MDEQ General Storm Water Permit (MIS049000) and the HCMA's plans for addressing each element. These actions comply with the regulations and meet plan objectives. The actions are summarized and tabulated in Section IV of this plan. The HCMA will prepare a report, at the appropriate time, to the MDNRE and advise them of any changes in the plan.

For the purposes of this program **"outfall"** and **"point source"** are defined as a location where the storm water from a separate storm water conveyance under the jurisdiction of the HCMA passes into a water body, wetland, upland or into a conveyance or property under the ownership or jurisdiction of an entity other than the HCMA. **"Significant Illicit Discharge"** is a discharge that shows evidence of impairing water quality in the receiving water.

The HCMA believes that public and employee education as well as resident involvement is essential for protection and enhancement of our natural resources. For an IDEP to be effective there needs to be an ongoing Public Education Plan that meets the objectives for the community. The HCMA plans to coordinate its IDEP with its Public Education Plan to develop target audiences and messages.

1. Develop and implement a program to find and eliminate illicit discharges and illicit connections found during dry weather screening.

Task 1.1: **Develop a priority schedule for the inspection of all HCMA drains and outfalls for which coverage is requested.**

Description: The HCMA uses existing water quality data, knowledge of problem areas, existing work/inspection schedule, location of urbanized areas and other criteria to prioritize the inspection of the HCMA drains and outfalls. The schedule has allowed the inspection of all of the outfalls within 5 years of the original COC issuance. Per the new permit, HCMA will again inspect all outfalls during the next 5 years.

Responsibility: Engineering Department is responsible for implementation
Measure: A written inspection schedule
Schedule: Complete within next 5 years

Task 1.2: **Perform visual inspections and dry weather screenings of HCMA owned and/or operated storm water conveyance outfalls.**

Description: Based on the schedule developed in Task 1.1. dry weather visual inspections will be conducted at each of the HCMA's known outfalls shown in Exhibit D. In instances where the outfall is submerged, directed to another enclosed sewer, or is otherwise inaccessible, the HCMA will visually inspect the nearest upstream accessible location.

Dry weather inspections are defined as those conducted when no rain/precipitation event has occurred for a minimum of 48 hours. Dry-weather screening at discharge point will include water clarity, color, and odor; the presence of suds, oil sheens, sewerage, floatable materials, bacterial sheens, algae, and slimes; staining of banks and unusual vegetative growth. Drainage structure shall be screened for unusual vegetative growth, staining, undocumented connections, and integrity of structure. If flow is observed in the sewer at that time, the flow will be tested to determine if the flow is natural base flow or a possible illicit discharge. Testing parameters will be pH, ammonia, surfactants, and temperature.

Responsibility: Engineering Department is responsible for implementation

Measure: Documentation of findings and observations. Number of possible illicit connections discovered.

Schedule: Complete all evaluations by the 5th year.

Task 1:3 **Trace Illicit Connections and Owner Notification**

Description: Trace suspected illicit connections found in Task 1:2 to their source using the techniques described below. If the illicit connection or discharge is a direct discharge to a HCMA-owned conveyance, then the HCMA will direct the owner of the source to eliminate the illicit connection/discharge within a specified timeframe and require a notification of correction. If the illicit discharge is to another jurisdiction's storm water conveyance and reaches a HCMA conveyance indirectly, then the HCMA will direct the owner of the system to provide updates on their investigation and inform the HCMA when the connection has been eliminated. The timeframe for eliminating the connection/discharge will depend on the type and significance of the illicit connection/discharge, and the expense and difficulty of repair. The goal of the plan is to have most illicit connections/discharges eliminated within 90 days of notification. Illicit connections/discharges that are more complex may take longer than 90 days to eliminate.

Tracing techniques - All storm outfalls that are discharging during dry weather will be investigated further. The HCMA may be able to locate the source of an illicit connection/discharge solely through visual observation. Odor, color, turbidity, bacteria growth, quantity of flow, etc., may lead to the source of a problem without additional sampling. As needed, sampling, dye and/or smoke testing, as-built plan review, or other investigative techniques will be used to determine the nature and source of the flow.

1. Sampling - Investigation of dry weather discharges will be prioritized based on the number of discharges identified, as well as other factors including location, volume of flow, and suspected contaminants based on color, turbidity, or odor. If flow is observed during the dry weather outfall inspections but visual observations do not lead to a source, the HCMA may decide to sample the flow for pollutant parameters typically found in illicit connections. Sampling can rule out some dry weather discharges such as groundwater. The sampling will typically begin at the outfall and continue upstream from access site to access site until a source is found. The choice of sampling parameters will depend on several factors including:
    - Location of the storm outfall (i.e., in residential or commercial area);
    - Turbidity and color of discharge which could distinguish between an illicit discharge from a commercial establishment versus a residence;
    - Odor associated with discharge such as petroleum, or raw sewage.

The HCMA may choose to analyze the samples for some or all of the following parameters:

Parameters	Found In	Potential Source(s)
Escherichia coli	Sewage	**Human or Animal Waste**
Surfactants	Soap, Emulsifiers	**Industrial/Commercial/ Residential**
Ammonia	Sewage, Fertilizers, Industrial Chemicals	**Industrial/Residential/ Agricultural**
Nitrates	Sewage, Fertilizers, Industrial Chemicals	**Fertilizers/ Industrial/ Residential/Agricultural**
Nitrites	Sewage, Fertilizers, Industrial Chemicals	**Fertilizers/ Industrial/ Residential/Agricultural**
Conductivity	Industrial Waste, Sewage, Salt	**Industrial/ Residential/ Agricultural**
Total Dissolved Solids	Industrial Waste, Sewage, Salt	**Industrial/Residential/ Agricultural**
Temperature	Cooling Water, Sewage	**Industrial/ Residential**
pH	Acids and Bases	**Industrial/ Residential**

2. As-built plan review - Where available, the HCMA will utilize as-built pipe schematic drawings as a tool to determine the source of an illicit connection/discharge.
3. Dye or smoke testing - The HCMA will conduct physical inspection of its facilities as needed to verify suspected illicit connections that are detected through visual observations/sampling of outfalls and manholes. As necessary, facility inspections will include dye or smoke testing of suspect facility plumbing fixtures to determine if the fixture discharges to the sanitary system or to the storm sewer. All facility inspections will be documented.
   Televising - The HCMA may elect to televise those enclosed storm sewers that have suspicious flows to identify pollutant sources that cannot be located through simple visual observation and/or sampling.
4. The HCMA may elect to conduct wet weather observations of some outfalls to determine if runoff from certain areas is contaminated. All outfall inspections will be documented.

Responsibility: The Engineering Department is responsible for implementation

Measure: Number of illicit connections/discharges traced and documentation of notification and elimination.

Schedule: On-going, continue until all illicit connections are traced.

Task 1.4: **Coordination with the MDNRE**

Description: The HCMA will report any identified significant illicit discharges including those of untreated or partially treated sewage to the MDNRE within 24 hours after the discharge begins or is discovered and of corrective actions being taken to eliminate the connection/discharge. The reports will cover the information required by the General Permit and Certificate of Coverage. If the discharge is of sewage, the HCMA will follow the reporting requirements of Section 324.112a of Part 31 of Public Act 451 of 1994, as amended including the notification of the local health department and daily newspaper and the use of the MDNRE web-based form.

Responsibility: The Engineering Department will be for responsible for implementation
Measure: Copy of the referral and/or annual report
Schedule: On-going

Task 1.5: **Provide training to appropriate HCMA staff on illicit connections and discharges, failed OSDS, safety issues and natural occurring phenomenon. Determine the feasibility of coordinating this training with the other agencies and the local communities in the County.**
Description: As an individual or coordinated effort, the HCMA will provide training on illicit connections and discharges, failed OSDS safety issues and natural occurring phenomenon to appropriate HCMA staff. Where appropriate, HCMA will attempt to coordinate IDEP training with the other local communities and the County Drain Commissioner, road commission, county health department, etc.
Responsibility: The Engineering Department is responsible for implementation
Measure: Meeting minutes, conclusions and recommendations. Training records.
Schedule: On-going

Task 1.6: **Review existing legal authority to implement the IDEP.**
Description: The HCMA does not have regulatory powers or have the ability to implement ordinances. The HCMA will however, insure compliance with all ordinances and regulations regarding HCMA owned and operated facilities and projects undertaken by HCMA. Should an illicit discharge from another municipality or source other than an HCMA owned facility be discovered on HCMA property, it will work closely with the municipality and / or other agencies to rectify the problem.
Responsibility: The Engineering Department is responsible for implementation

Task 1.7: **Notify proper jurisdictions of illicit discharges or connections found by HCMA staff.**
Description: During the course of normal business, staff of the HCMA may observe illicit connections or discharges that are not under the HCMA‘s jurisdiction. The HCMA will notify the owner or agency with jurisdiction of the problem in writing. The HCMA will report any identified significant illicit discharges including those of untreated or partially treated sewage to the MDNRE within 24 hours after the discharge begins or is discovered and of corrective actions being taken to eliminate the connection/discharge. The reports will cover the information required by the General Permit and Certificate of Coverage. If the discharge is of sewage, the HCMA will follow the reporting requirements of Section 324.112a of Part 31 of Public Act 451 of 1994, as amended including the notification of the local health department and daily newspaper and the use of the MDNRE web-based form.

The HCMA will submit a report as required to MDNRE summarizing the activities completed including illicit connections and discharges HCMA identified and corrected. For significant illicit discharges, the HCMA will list the pollutants of concern, the estimated load and volume discharged, and the locations of the discharge into the system and to the waters of the state. For unresolved sewage discharges, the report will follow the reporting requirements of Section 324.112a of Part 31 of Public Act 451 of 1994, as amended.

Responsibility: The Engineering Department is responsible for implementation
Measure: Documentation of the notification
Schedule: On-going

Task 1.8: **Review any existing water quality data for drains and water bodies in the HCMA**
Description: The HCMA will obtain and review any available water quality data for the water bodies in the HCMA affected by this permit. Possible sources are the County Drain Commissioner and Health Department records, Michigan Department of Natural Resources & Environment (MDNRE), the Clinton River and Huron River Watershed Councils, local universities and local communities. The review will be used to assist the HCMA in prioritizing actions and tracking progress for the IDEP.
Responsibility: The Engineering Department is responsible for implementation
Measure: Documentation of review and recommendations
Schedule: On-going

Task 1.9: **Investigate the feasibility/benefit of conducting base-line and then follow-up water quality monitoring in select drains and water bodies in the HCMA.**
Description: The HCMA will investigate the feasibility and benefit of conducting base-line and periodic follow-up water quality monitoring in select drains and water bodies in the HCMA. The monitoring may provide a measure of the effectiveness of the IDEP. The HCMA will look at costs versus value of information obtained and decide if monitoring will be added as an additional IDEP task.
Responsibility: The Engineering Department is responsible for implementation
Measure: Documentation of evaluation, conclusions and recommendations.
Schedule: On-going.

Task 1.10: **Develop and adopt construction specifications that require contractors working in the HCMA to report any illicit connections and discharges they may observe.**
Description: The HCMA will adopt construction specifications to require contractors that are working on sewers, drains, etc. within the HCMA to report all illicit connections and discharges they observe to the HCMA.
Responsibility: The Engineering Department is responsible for implementation
Measure: Documentation of adoption, records of reports.
Schedule: On-going.

2. Develop and implement a program to minimize seepage from sanitary sewers and on-site sewage disposal systems (OSDS) into the applicant's separate storm water drainage system.

Task 2.1: **Provide training to appropriate HCMA staff on illicit connections and discharges, failed OSDS, safety issues and natural occurring phenomenon. Determine the feasibility of coordinating this training with the other agencies and the local communities in the County.**

Description: The HCMA will provide training on illicit connections and discharges, including failed OSDS to appropriate HCMA staff. The HCMA will attempt to coordinate IDEP training with the other local communities and the Drain Commissioner, road commission, county health department, etc.

Responsibility: The Engineering Department is responsible for implementation

Measure: Meeting minutes, conclusions and recommendations. Training records.

Schedule: On-going

Task 2.2: **The HCMA will take action to identify failed OSDS to HCMA facilities.**

Description: The HCMA will take the following actions to locate failing OSDS.

- HCMA field employees will be trained to identify failed OSDS so in their daily routine they can assist in locating these areas of concern.
- OSDS failures may be identified as part of the outfall/sewer observations and sampling.
- visual inspections of the shore/banks of lakes, streams and open drains near HCMA facilities.

Responsibility: The Engineering Department is responsible for implementation

Measure: Complaint and referral records.

Schedule: On going

Task 2.3: **Evaluate the integrity of the HCMA sanitary systems.**

Description: The HCMA will coordinate the evaluation of the sanitary systems, sewers and OSDS, at HCMA-owned and -operated facilities within the coverage area, to insure that seepage into the groundwater and surface water is minimized. The evaluation may include visual inspection, flow record review, sewer televising and other means as appropriate.

Responsibility: The Engineering Department is responsible for implementation

Measure: Report of findings, corrections and/or recommendations

Schedule: On-going.

Task 2.4: **Investigate the feasibility of performing visual observations of lake shorelines and river banks in the HCMA to find potential illicit OSDS discharges.**

Description: The HCMA will investigate the feasibility and benefit of conducting visual inspections of the shorelines and banks of the water bodies and courses within the coverage area of the HCMA.

Responsibility: The Engineering Department is responsible for implementation

Measure: Documentation of evaluation, conclusions and recommendations.

Schedule: On-going.

Task 2.5: **Televise storm sewers as needed to detect illicit connections.**

Description: On an as-needed basis, the HCMA may televise those separate storm sewers under its jurisdiction to determine if illicit connections that were not detected during outfall inspections/sampling exist.

Responsibility: The Engineering Department responsible for implementation
Measure: videos of work.
Schedule: On-going

3. Develop a method for determining the effectiveness of the illicit discharge elimination activities which shall, at a minimum, result in the inspection of each storm water point source every five years unless an alternative schedule is approved by the MDNRE.

Task 3.1: **Perform visual inspections and dry weather screenings of HCMA-owned and/or -operated storm water conveyance outfalls.**
Description: Visual inspections will be conducted for each of the HCMA's known outfalls shown in Exhibit D during dry weather. In instances where the outfall is submerged, directed to another enclosed sewer, or is otherwise inaccessible, the HCMA will visually inspect the nearest accessible upstream location.
Dry weather inspections are defined as those conducted when no rain/precipitation event has occurred for a minimum of 48 hours. If flow is observed in the sewer at that time, it will be determined if the flow is natural base flow or possibly due to illicit discharges.
Responsibility: The Engineering Department is responsible for implementation
Measure: Documentation of findings and observations. Number of possible illicit connections/discharges discovered.
Schedule: Complete all evaluations and visual inspection every 5 years.

Task 3.2: **Investigate the feasibility/benefit of conducting base-line and then follow-up water quality monitoring in select drains and water bodies in the HCMA.**
Description: The HCMA will investigate the feasibility and benefit of conducting base-line and periodic follow-up water quality monitoring in select drains and water bodies in the HCMA. The monitoring may provide a measure of the effectiveness of the IDEP. The HCMA will look at costs versus value of information obtained and decide if monitoring will be added as an additional IDEP task.
Responsibility: The Engineering Department is responsible for implementation
Measure: Documentation of evaluation, conclusions and recommendations.
Schedule: On-going.

Task 3.3: **Develop and implement a procedure to identify and record, map and inspect outfalls from new construction.**
Description The HCMA will develop and implement a procedure to add any new outfalls within the coverage area that result from new construction. The procedure will involve identifying new outfalls and receiving waters through construction approval process, adding the outfalls to the existing drainage system map, and performing an initial dry weather inspection of the outfall.
Responsibility: The Engineering Department is responsible for implementation
Measure: Procedure documented and implemented. New outfalls mapped and inspected.
Schedule: Ongoing

4. Prepare an updated map of the location of each known storm water point source and the respective receiving water or drainage system.

Task 4.1: **Update drainage system map based on field observations.**
Description: The HCMA will complete a field verification of the storm conveyance system and outfalls that are owned and/or operated by the HCMA within the coverage area, based on the existing maps. This verification may be completed during the initial dry weather inspection, follow-up inspections or as a separate field reconnaissance. The drainage system map and outfall table will be updated based on the field observations.
Responsibility: The Engineering Department is responsible for implementation
Measure: Outfall map and table updated.
Schedule: On-going.

Task 4.2: **Inventory and identify ownership of the significant storm water conveyances within the HCMA and address ownership of any "orphan" drains.**
Description: Determine ownership of the significant storm water conveyances within the HCMA and initiate a process to verify ownership or petition the Drain Commissioner to accept responsibility of any "orphan" drains - those with no known ownership.
Responsibility: The Engineering Department is responsible for implementation
Measure: Documentation of evaluation and decision.
Schedule: On-going.

Task 4.3: **Develop and implement a procedure to identify and record, map, and inspect outfalls from new construction.**
Description The HCMA will develop and implement a procedure to add any new outfalls that result from new construction within the requested coverage area. The procedure will involve identifying new outfalls and receiving waters through construction approval process, adding the outfalls to the existing drainage system map, and performing an initial dry weather inspection of the outfall.
Responsibility: Te Engineering Department is responsible for implementation
Measure: Procedure documented and implemented. New outfalls mapped and inspected.
Schedule: On-going.

Post Construction Storm Water Control for New Developments and Redevelopment Projects

Updated July 2008, February 2010

Much of the Metroparks current 5 year Plan is devoted to the maintenance, improvement or redevelopment of existing Metropark facilities. Post Construction and Redevelopment projects have the potential to negatively effect local waters through picking up harmful sediment and chemicals in runoff from construction sites and depositing them in local waterways, and by increasing the quantity of water delivered to the water body during storms due to the increased impervious surface of the developed area. The focus of this measure will be to minimize the effect of post construction and redevelopment activities within the Metroparks on the surrounding water bodies through various means including:

1. Comprehensive master planning to guide the Metroparks development away from sensitive areas
2. Proper site planning that minimizes impacts to the site.
3. Cooperating with state and local agencies.
4. Include appropriate post construction BMPs into construction documents.
5. Construction activity inspection by Metroparks field staff to ensure BMP compliance.
6. Enforcement of BMP compliance within construction document provisions.
7. Implement post-construction maintenance BMPs to minimize negative operational impacts.

In the past 60 years, the Metroparks has established and maintained over 24,000 acres of park land. Master plans have been developed for each site taking into account the topography, soils, hydrology, vegetation, wildlife and other esthetic and non-esthetic qualities of the area. Development within the park system follows these master planning guidelines to help ensure proper location of Metropark facilities whether they are active or passive use. New development site planning by Metroparks staff further ensures that all site specific considerations will be taken into account when developing Metropark facilities which will aid in minimizing negative impacts to the area. Non-structural BMPs such as maximization of open space, minimizing disturbance and the use of buffer zones are all used in this planning process.

Current and past practice in the Metroparks for the design and construction of roads, lots and site developments has typically incorporated turf or vegetative swales for drainage of storm water runoff. Broad, shallow roadsides and lot-side turf ditches predominate throughout the parks, with cross-culverts where necessary. This practice is made possible due to the typically generous land areas available for development within the Metroparks. The use of catch basins and culverts for storm water conveyance is typically limited to intensively developed areas such as parking lots and plazas associated with pool and play activity areas. Projects involving earthwork or site development incorporate soil erosion control measures in accordance with the Soil Erosion Act, PA 451 of 1994. Other structural BMPs including storm water storage, infiltration practices and the use of native vegetative plantings and landscaping features will be incorporated to further maximize program effectiveness. The development and implementation of BMPs is a critical component of the measure. In order to facilitate the implementation process, the Metroparks will initiate the use of EPA NPDES BMP guidelines in this pollution prevention process as indicated at the end of this document and/or develop specific Metroparks BMPs as appropriate.

The Metroparks do not have regulatory powers or the ability to implement ordinances. The Metroparks will however, ensure compliance with all state and local ordinances and regulations regarding Metroparks owned and operated facilities and construction projects undertaken by the Metroparks. The Metroparks will follow the *minimum treatment volume standard* or *channel protection criteria* as required by the County Agency the Park is located in unless an alternative approach is deemed applicable. All development planning, engineering and construction activity that occurs within the Metroparks is administered and supervised by staff of the Metroparks Planning and Engineering Departments. In addition, construction plans are routinely submitted for site plan review to the local community having jurisdiction over that particular Metropark. At each construction site, staff of the Metroparks Engineering or Planning Departments routinely oversee construction activities and monitor compliance with the job specifications, contract documents and local ordinances. In addition, the Metroparks also employs a certified storm water operator. Whether the construction activities are carried out through a contract or by park forces, there is a high degree of control during the construction process which will help ensure compliance with storm water BMP applications.

Task: Through proper planning, construction techniques and maintenance practices, the Metroparks will provide and implement storm water runoff controls which will minimize or prevent negative impacts on water quality from post construction activity of new or re-development projects. These measures will be based on current best available technology and field experience.

Description: 1. The Metroparks will continue to incorporate and refine the Master Planning process when considering Metroparks developments. All pertinent information including topography, soils, hydrology and wildlife will be incorporated into the decision making process during site planning to help minimize negative effects to adjacent water bodies.

2. The Metroparks will incorporate storm water management BMPs in the design, construction and maintenance of new and redeveloped projects on Metroparks properties.

3. The Metroparks and its contractors will comply with all soil erosion control measures in accordance with the Soil Erosion Act, Act 91 of Pa. 541 of 1994.

4. Supervision by Metroparks staff will be in place for all construction activity to ensure regulation compliance.

5. Where appropriate and feasible, the Metroparks will implement storm water BMPs to minimize potential water quality impact of Metropark facilities. These BMPs would include:

- Proper site planning, preserving natural vegetation within the project site, minimizing vegetation clearing and tree planting.
- Using check dams, filter berms and grass-lined channels, detention ponds and wetland systems to control run-off.
- Using mulch, temporary and permanent seeding or sodding to stabilize exposed soils.
- Installation of diversion dikes, silt fence, sediment basins, sediment traps and sediment chambers and sediment filters at storm drain inlets.
- The use of mulch and geotextiles to protect steep slopes.
- Maintaining vegetative buffers along waterways.
- BMP Inspection and Maintenance.

6. The Metroparks will, when prudent and feasible, use native plant material in non use areas. Where cool season grasses are required, the Metroparks will use sound agronomic practices, such as those used in the Michigan Turfgrass Environmental Stewardship Program, for the installation and maintenance of turf.

Responsibility: The Metroparks Planning and Engineering Departments are responsible for administration and implementation of the SWMPP. Park operations will be responsible for daily maintenance and monitoring of facilities. Information, complaints or other feedback from the public regarding construction site storm water management can be addressed at any park facility, park office, via e-mail to the Metroparks web site or toll free phone number to the Metroparks. All inquiries will be directed to Michael Arens, Chief Engineer and administrator for the Metroparks Phase II Storm Water Management Program Plan.

POST-CONSTRUCTION STORM WATER CONTROL FOR NEW DEVELOPMENTS & REDEVELOPMENT PROJECTS – BEST MANAGEMENT PRACTICES (BMPS)

DRY EXTENDED DETENTION POND

Description

Dry extended detention ponds (a.k.a. dry ponds, extended detention basins, detention ponds, extended detention ponds) are basins whose outlets have been designed to detain the storm water runoff from a water quality design storm for some minimum time (e.g., 24 hours) to allow particles and associated pollutants to settle. Unlike wet ponds, these facilities do not have a large permanent pool. However, they are often designed with small pools at the inlet and outlet of the basin. They can also be used to provide flood control by including additional flood detention storage.

Applicability

Dry extended detention ponds are among the most widely applicable storm water management practices. Although they have limited applicability in highly urbanized settings, they have few other restrictions.

Regional Applicability

Dry extended detention ponds can be applied in all regions of the United States. Some minor design modifications might be needed, however, in cold or arid climates or in regions with karst (i.e. limestone) topography.

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface is present. It is difficult to use dry extended detention ponds in the ultra-urban environment because of the land area each pond consumes. They can, however, be used in an ultra-urban environment if a relatively large area is available downstream of the pond.

Storm Water Hot Spots

Storm water hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. Dry extended detention ponds can accept runoff from storm water hot spots, but they need significant separation from ground water if they will be used for this purpose.

Storm Water Retrofit

A storm water retrofit is a storm water management practice (usually structural) put into place after development has occurred to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Dry extended detention ponds are very useful storm water retrofits, and they have two primary applications as a retrofit design. In many communities in the past, detention basins have been designed for flood control. It is possible to modify these facilities to incorporate features that encourage water quality control and/or channel protection. It is also possible to construct new dry ponds in open areas of a watershed to capture existing drainage.

Cold Water (Trout) Streams

A study in Prince George's County, Maryland, found that storm water management practices can increase stream temperatures (Galli, 1990). Overall, dry extended detention ponds increased temperature by about 5°F. In cold water streams, dry ponds should be designed to detain storm water for a relatively short time (i.e., less than 12 hours) to minimize the amount of warming that occurs in the practice.

Siting and Design Considerations

Siting Considerations

Although dry extended detention ponds can be applied rather broadly, designers need to ensure that they are feasible at the site in question. This section provides basic guidelines for siting dry extended detention ponds.

<u>Drainage Area</u>

In general, dry extended detention ponds should be used on sites with a minimum area of 10 acres. On smaller sites, it can be challenging to provide channel or water quality control because the orifice diameter at the outlet needed to control relatively small storms becomes very small and thus prone to clogging. In addition, it is generally more cost-effective to control larger drainage areas due to the economies of scale (see Cost Considerations).

Slope

Dry extended detention basins can be used on sites with slopes up to about 15 percent. The local slope needs to be relatively flat, however, to maintain reasonably flat side slopes in the practice. There is no minimum slope requirement, but there does need to be enough elevation drop from the pond inlet to the pond outlet to ensure that flow can move through the system.

Soils / Topography

Extended detention basins can be used with almost all soils and geology, with minor design adjustments for regions of karst topography or in rapidly percolating soils such as sand. In these areas, extended detention ponds should be designed with an impermeable liner to prevent ground water contamination or sinkhole formation.

Ground Water

Except for the case of hot spot runoff, the only consideration regarding ground water is that the base of the extended detention facility should not intersect the ground water table. A permanently wet bottom may become a mosquito breeding ground. Research in Southwest Florida (Santana et al., 1994) demonstrated that intermittently flooded systems, such as dry extended detention ponds, produce more mosquitoes than other pond systems, particularly when the facilities remained wet for more than 3 days following heavy rainfall.

Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. Some features, however, should be incorporated into most dry extended detention pond designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

Pretreatment

Pretreatment incorporates design features that help to settle out coarse sediment particles. By removing these particles from runoff before they reach the large permanent pool, the maintenance burden of the pond is reduced. In ponds, pretreatment is achieved with a sediment forebay, which is a small pool (typically about 10 percent of the volume of water to be treated for pollutant removal).

Treatment

Treatment design features help enhance the ability of a storm water management practice to remove pollutants. Designing dry ponds with a high length-to-width ratio (i.e., at least 1.5:1) and incorporating other design features to maximize the flow path effectively increases the detention time in the system by eliminating the potential of flow to short-circuit the pond. Designing ponds with relatively flat side slopes can also help to lengthen the effective flow path. Finally, the pond should be sized to detain the volume of runoff to be treated for between 12 and 48 hours.

Conveyance

Conveyance of storm water runoff into and through a storm water management practice is a critical component of any such practice. Storm water should be conveyed to and from practices safely in a manner that minimizes erosion potential. The outfall of pond systems should always be stabilized to prevent scour. To convey low flows through the system, designers should provide a pilot channel. A pilot channel is a surface channel that should be used to convey low flows through the pond. In addition, an emergency spillway should be provided to safely convey large flood events. To help mitigate warming at the outlet channel, designers should provide shade around the channel at the pond outlet.

Maintenance Reduction

In addition to regular maintenance activities needed to maintain the function of storm water practices, some design features can be incorporated to ease the maintenance burden of each practice. In dry extended detention ponds, a "micropool" at the outlet can prevent resuspension of sediment and outlet clogging. A good design includes maintenance access to the forebay and micropool.

Another design feature that can reduce maintenance needs is a non-clogging outlet. Typical examples include a reverse-slope pipe or a weir outlet with a trash rack. A reverse slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and determines the water elevation of the micropool.

Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris.

Landscaping

Designers should maintain a vegetated buffer around the pond and should select plants within the extended detention zone (i.e., the portion of the pond up to the elevation where storm water is detained) that can withstand both wet and dry periods. The side slopes of dry ponds should be relatively flat to reduce safety risks.

Design Variations

Dry Detention Ponds

Dry detention ponds are similar in design to extended detention ponds, except that they do not incorporate features to improve water quality. In particular, these practices do not detain storm water from small-flow events. Therefore, detention ponds provide almost no pollutant removal. However, dry ponds can help to meet flood control, and sometimes channel protection, objectives in a watershed.

Tank Storage

Another variation of the dry detention pond design is the use of tank storage. In these designs, storm water runoff is conveyed to large storage tanks or vaults underground. This practice is most often used in the ultra-urban environment, on small sites where no other opportunity is available to provide flood control. Tank storage is provided on small areas because providing underground storage for a large drainage area would generally be cost-prohibitive. Because the drainage area contributing to tank storage is typically small, the outlet diameter needed to reduce the flow from very small storms would very small. A very small outlet diameter, along with the underground location of the tanks, creates the potential for debris being caught in the outlet and resulting maintenance problems. Since it is necessary to control small runoff events (such as the runoff from a 1-inch storm) to improve water quality, it is generally infeasible to use tank storage for water quality and generally impractical to use it to protect stream channels.

Regional Variations

Arid or Semi-Arid Climates

In arid and semi-arid regions, some modifications might be needed to conserve scarce water resources. Any landscaping plans should prescribe drought-tolerant vegetation wherever possible. In addition, the wet forebay can be replaced with an alternative dry pretreatment, such as a detention cell. One opportunity in regions with a distinct wet and dry season, as in many arid regions, is to use regional extended detention ponds as a recreation area such as a ball field during the dry season.

Cold Climates

In cold climates, some additional design features can help to treat the spring snowmelt. One such modification is to increase the volume available for detention to help treat this relatively large runoff event. In some cases, dry facilities may be an option as a snow storage facility to promote some treatment of plowed snow. If a pond is used to treat road runoff or is used for snow storage, landscaping should incorporate salt-tolerant species. Finally, sediment might need to be removed from the forebay more frequently than in warmer climates (see Maintenance Considerations for guidelines) to account for sediment deposited as a result of road sanding.

Limitations

Although dry extended detention ponds are widely applicable, they have some limitations that might make other storm water management options preferable:

- Dry extended detention ponds have only moderate pollutant removal when compared to other structural storm water practices, and they are ineffective at removing soluble pollutants (See Effectiveness).
- Dry extended detention ponds may become a nuisance due to mosquito breeding.
- Habitat destruction may occur during construction if the practice is designed in-stream or within the stream buffer.
- Although wet ponds can increase property values, dry ponds can actually detract from the value of a home (see Cost Considerations).

Dry extended detention ponds on their own only provide peak flow reduction and do little to control overall runoff volume, which could result in adverse downstream impacts.

Maintenance Considerations

In addition to incorporating features into the pond design to minimize maintenance, some regular maintenance and inspection practices are needed. Table 1 outlines some of these practices.

Table 1. Typical maintenance activities for dry ponds (Source: Modified from WMI, 1997)

Activity	**Schedule**
• Note erosion of pond banks or bottom	Semiannual inspection
• Inspect for damage to the embankment • 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 • Mow side slopes • Manage pesticide and nutrients • Remove litter and debris	Standard maintenance
• Seed or sod to restore dead or damaged ground cover	Annual maintenance (as needed)
• Remove sediment from the forebay	5- to 7-year maintenance
• Monitor sediment accumulations, and remove sediment when the pond volume has been reduced by 25 percent	25- to 50-year maintenance

Effectiveness

Structural management practices can be used to achieve four broad resource protection goals: flood control, channel protection, ground water recharge, and pollutant removal. Dry extended detention basins can provide flood control and channel protection, as well as some pollutant removal.

Flood Control

One objective of storm water management practices can be to reduce the flood hazard associated with large storm events by reducing the peak flow associated with these storms. Dry extended detention basins can easily be designed for flood control, and this is actually the primary purpose of most extended detention ponds.

Channel Protection

One result of urbanization is the geomorphic changes that occur in response to modified hydrology. Traditionally, dry extended detention basins have provided control of the 2-year storm (i.e., the storm that occurs, on average, once every 2 years) for channel protection. It appears that this control has been relatively ineffective, and recent research suggests that control of a smaller storm might be more appropriate (MacRae, 1996). Slightly modifying the design of dry extended detention basins to reduce the flow of smaller storm events might make them effective tools in reducing downstream erosion.

Pollutant Removal

Dry extended detention basins provide moderate pollutant removal, provided that the design features described in the Siting and Design Considerations section are incorporated. Although they can be effective at removing some pollutants through settling, they are less effective at removing soluble pollutants because of

the absence of a permanent pool. A few studies are available on the effectiveness of dry extended detention ponds. Typical removal rates, as reported by Schueler (1997), are as follows:
Total suspended solids: 61%
Total phosphorus: 19%
Total nitrogen: 31%
Nitrate nitrogen: 9%
Metals: 26%–54%
There is considerable variability in the effectiveness of ponds, and it is believed that properly designing and maintaining ponds may help to improve their performance. The siting and design criteria presented in this sheet reflect the best current information and experience to improve the performance of wet ponds. A recent joint project of the American Society of Civil Engineers (ASCE) and the USEPA Office of Water might help to isolate specific design features that can improve performance. The National Storm Water Best Management Practice (BMP) database is a compilation of storm water practices that includes both design information and performance data for various practices. As the database expands, inferences about the extent to which specific design criteria influence pollutant removal may be made. For more information on this database, access the BMP database web page at http://www.bmpdatabase.org

WET PONDS

Description

Wet ponds (a.k.a. storm water ponds, retention ponds, wet extended detention ponds) are constructed basins that have a permanent pool of water throughout the year (or at least throughout the wet season). Ponds treat incoming storm water runoff by settling and algal uptake. The primary removal mechanism is settling as storm water runoff resides in this pool, and pollutant uptake, particularly of nutrients, also occurs through biological activity in the pond. Wet ponds are among the most cost-effective and widely used storm water practices. While there are several different versions of the wet pond design, the most common modification is the extended detention wet pond, where storage is provided above the permanent pool in order to detain storm water runoff in order to provide settling.

Applicability

Wet ponds are widely applicable storm water management practices. Although they have limited applicability in highly urbanized settings and in arid climates, they have few other restrictions.

Regional Applicability

Wet extended detention ponds can be applied in most regions of the United States, with the exception of arid climates. In arid regions, it is difficult to justify the supplemental water needed to maintain a permanent pool because of the scarcity of water. Even in semi-arid Austin, Texas, one study found that 2.6 acre-feet per year of supplemental water was needed to maintain a permanent pool of only 0.29 acre-feet (Saunders and Gilroy, 1997). Other modifications and design variations are needed in semi-arid and cold climates, and karst (i.e., limestone) topography.

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface exists. It is difficult to use wet ponds in the ultra-urban environment because of the land area each pond consumes. They can, however, be used in an ultra-urban environment if a relatively large area is available downstream of the site.

Storm Water Hot Spots

Storm water hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. A typical example is a gas station. Wet ponds can accept runoff from storm water hot spots, but need significant separation from ground water if they will be used for this purpose.

Storm Water Retrofit

A storm water retrofit is a storm water management practice (usually structural) put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Wet ponds are very useful storm water retrofits and have two primary applications as a retrofit design. In many communities, detention ponds have been designed for flood control in the past.

It is possible to modify these facilities to develop a permanent wet pool to provide water quality control (see Treatment under Design Considerations), and modify the outlet structure to provide channel protection. Alternatively, wet ponds may be designed in-stream, or in open areas as a part of a retrofit study.

Cold Water (Trout) Streams

Wet ponds pose a risk to cold water systems because of their potential for stream warming. When water remains in the permanent pool, it is heated by the sun. A study in Prince George's County, Maryland, found that storm water wet ponds heat storm water by about 9°F from the inlet to the outlet (Galli, 1990).

Siting and Design Considerations

Siting Considerations

In addition to the restrictions and modifications to adapting wet ponds to different regions and land uses, designers need to ensure that this management practice is feasible at the site in question. The following section provides basic guidelines for siting wet ponds.

<u>Drainage Area</u>

Wet ponds need sufficient drainage area to maintain the permanent pool. In humid regions, this is typically about 25 acres, but a greater area may be needed in regions with less rainfall.

<u>Slope</u>

Wet ponds can be used on sites with an upstream slope up to about 15 percent. The local slope should be relatively shallow, however. Although there is no minimum slope requirement, there does need to be enough elevation drop from the pond inlet to the pond outlet to ensure that water can flow through the system.

<u>Soils / Topography</u>

Wet ponds can be used in almost all soils and geology, with minor design adjustments for regions of karst topography (see Design Considerations).

<u>Ground Water</u>

Unless they receive hot spot runoff, ponds can often intersect the ground water table. However, some research suggests that pollutant removal is reduced when ground water contributes substantially to the pool volume (Schueler, 1997b).

Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. There are some features, however, that should be incorporated into most wet pond designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

<u>Pretreatment</u>

Pretreatment incorporates design features that help to settle out coarse sediment particles. By removing these particles from runoff before they reach the large permanent pool, the maintenance burden of the pond is reduced. In ponds, pretreatment is achieved with a sediment forebay. A sediment forebay is a small pool (typically about 10 percent of the volume of the permanent pool). Coarse particles remain trapped in the forebay, and maintenance is performed on this smaller pool, eliminating the need to dredge the entire pond.

<u>Treatment</u>

Treatment design features help enhance the ability of a storm water management practice to remove pollutants. The purpose of most of these features is to increase the amount of time that storm water remains in the pond.

One technique of increasing the pollutant removal of a pond is to increase the volume of the permanent pool. Typically, ponds are sized to be equal to the water quality volume (i.e., the volume of water treated for pollutant removal). Designers may consider using a larger volume to meet specific watershed objectives, such as phosphorous removal in a lake system. Regardless of the pool size, designers need to conduct a water balance analysis to ensure that sufficient inflow is available to maintain the permanent pool.

Other design features do not increase the volume of a pond, but can increase the amount of time storm water remains in the practice and eliminate short-circuiting. Ponds should always be designed with a length-to-width ratio of at least 1.5:1. In addition, the design should incorporate features to lengthen the flow path through the pond, such as underwater berms designed to create a longer route through the pond. Combining these two measures helps ensure that the entire pond volume is used to treat storm water. Another feature that can improve treatment is to use multiple ponds in series as part of a "treatment train" approach to pollutant removal. This redundant treatment can also help slow the rate of flow through the system.

<u>Conveyance</u>

Storm water should be conveyed to and from all storm water management practices safely and to minimize erosion potential. The outfall of pond systems should always be stabilized to prevent scour. In addition, an emergency spillway should be provided to safely convey large flood events. To help mitigate warming at the outlet channel, designers should provide shade around the channel at the pond outlet.

<u>Maintenance Reduction</u>

In addition to regular maintenance activities needed to maintain the function of storm water 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.

One potential maintenance concern in wet ponds is clogging of the outlet. Ponds should be designed with a non-clogging outlet such as a reverse-slope pipe, or a weir outlet with a trash rack. A reverse-slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and establishes the water elevation of the permanent pool. Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris. Another general rule is that no orifice should be less than 3 inches in diameter. (Smaller orifices are more susceptible to clogging).

Design features are also incorporated to ease maintenance of both the forebay and the main pool of ponds. Ponds should be designed with a maintenance access to the forebay to ease this relatively routine (5–7 year) maintenance activity. In addition, ponds should generally have a pond drain to draw down the pond for the more infrequent dredging of the main cell of the pond.

<u>Landscaping</u>

Landscaping of wet ponds can make them an asset to a community and can also enhance the pollutant removal of the practice. A vegetated buffer should be preserved around the pond to protect the banks from erosion and provide some pollutant removal before runoff enters the pond by overland flow. In addition, ponds should incorporate an aquatic bench (i.e., a shallow shelf with wetland plants) around the edge of the pond. This feature may provide some pollutant uptake, and it also helps to stabilize the soil at the edge of the pond and enhance habitat and aesthetic value.

Design Variations

There are several variations of the wet pond design. Some of these design alternatives are intended to make the practice adaptable to various sites and to account for regional constraints and opportunities.

<u>Wet Extended Detention Pond</u>

The wet extended detention pond combines the treatment concepts of the dry extended detention pond and the wet pond. In this design, the water quality volume is split between the permanent pool and detention storage provided above the permanent pool. During storm events, water is detained above the permanent pool and released over 12 to 48 hours. This design has similar pollutant removal to a traditional wet pond and consumes less space. Wet extended detention ponds should be designed to maintain at least half the treatment volume of the permanent pool. In addition, designers need to carefully select vegetation to be planted in the extended detention zone to ensure that the selected vegetation can withstand both wet and dry periods.

<u>Pocket Pond</u>

In this design alternative, a pond drains a smaller area than a traditional wet pond, and the permanent pool is maintained by intercepting the ground water. While this design achieves less pollutant removal than a traditional wet pond, it may be an acceptable alternative on sites where space is at a premium, or in a retrofit situation.

<u>Water Reuse Pond</u>

Some designers have used wet ponds to act as a water source, usually for irrigation. In this case, the water balance should account for the water that will be taken from the pond. One study conducted in Florida estimated that a water reuse pond could provide irrigation for a 100-acre golf course at about one-seventh the cost of the market rate of the equivalent amount of water ($40,000 versus $300,000).

Regional Adaptations

Semi-Arid Climates

In arid climates, wet ponds are not a feasible option (see Applicability), but they may possibly be used in semi-arid climates if the permanent pool is maintained with a supplemental water source, or if the pool is allowed to vary seasonally. This choice needs to be seriously evaluated, however. Saunders and Gilroy (1997) reported that 2.6 acre-feet per year of supplemental water were needed to maintain a permanent pool of only 0.29 acre-feet in Austin, Texas.

Cold Climates

Cold climates present many challenges to designers of wet ponds. The spring snowmelt may have a high pollutant load and a large volume to be treated. In addition, cold winters may cause freezing of the permanent pool or freezing at inlets and outlets. Finally, high salt concentrations in runoff resulting from road salting, and sediment loads from road sanding, may impact pond vegetation as well as reduce the storage and treatment capacity of the pond.

One option to deal with high pollutant loads and runoff volumes during the spring snowmelt is the use of a seasonally operated pond to capture snowmelt during the winter, and retain the permanent pool during warmer seasons. In this option, proposed by Oberts (1994), the pond has two water quality outlets, both equipped with gate valves. In the summer, the lower outlet is closed. During the fall and throughout the winter, the lower outlet is opened to draw down the permanent pool. As the spring melt begins, the lower outlet is closed to provide detention for the melt event. This method can act as a substitute for using a minimum extended detention storage volume. When wetlands preservation is a downstream objective, seasonal manipulation of pond levels may not be desired. An analysis of the effects on downstream hydrology should be conducted before considering this option. In addition, the manipulation of this system requires some labor and vigilance; a careful maintenance agreement should be confirmed.

Several other modifications may help to improve the performance of ponds in cold climates. Designers should consider planting the pond with salt-tolerant vegetation if the facility receives road runoff. In order to counteract the effects of freezing on inlet and outlet structures, the use of inlet and outlet structures that are resistant to frost, including weirs and larger diameter pipes, may be useful. Designing structures on-line, with a continuous flow of water through the pond, will also help prevent freezing of these structures. Finally, since freezing of the permanent pool can reduce the effectiveness of pond systems, it may be useful to incorporate extended detention into the design to retain usable treatment area above the permanent pool when it is frozen.

Karst Topography

In karst (i.e., limestone) topography, wet ponds should be designed with an impermeable liner to prevent ground water contamination or sinkhole formation, and to help maintain the permanent pool.

Limitations

Limitations of wet ponds include:

- If improperly located, wet pond construction may cause loss of wetlands or forest.
- Although wet ponds consume a small amount of space relative to their drainage areas, they are often inappropriate in dense urban areas because each pond is generally quite large.
- Their use is restricted in arid and semi-arid regions due to the need to supplement the permanent pool.
- In cold water streams, wet ponds are not a feasible option due to the potential for stream warming.
- Wet ponds may pose safety hazards.

Maintenance Considerations

In addition to incorporating features into the pond design to minimize maintenance, some regular maintenance and inspection practices are needed. The table below outlines these practices.

Table 1. Typical maintenance activities for wet ponds (Source: WMI, 1997)

Activity	Schedule
• If wetland components are included, inspect for invasive vegetation.	Semi-annual inspection
• Inspect for damage. • 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 operational.	Annual inspection
• Repair undercut or eroded areas.	As needed maintenance
• Clean and remove debris from inlet and outlet structures. • Mow side slopes.	Monthly maintenance
• Manage and harvest wetland plants.	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 or the pond becomes eutrophic.	20-to 50-year maintenance

Effectiveness

Structural storm water management practices can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. Wet ponds can provide flood control, channel protection, and pollutant removal.

Flood Control

One objective of storm water management practices can be to reduce the flood hazard associated with large storm events by reducing the peak flow associated with these storms. Wet ponds can easily be designed for flood control by providing flood storage above the level of the permanent pool.

Channel Protection

When used for channel protection, wet ponds have traditionally controlled the 2-year storm. It appears that this control has been relatively ineffective, and recent research suggests that control of a smaller storm may be more appropriate (MacRae, 1996).

Ground Water Recharge

Wet ponds cannot provide ground water recharge. Infiltration is impeded by the accumulation of debris on the bottom of the pond.

Pollutant Removal

Wet ponds are among the most effective storm water management practices at removing storm water pollutants. A wide range of research is available to estimate the effectiveness of wet ponds. Table 2 summarizes some of the research completed on wet pond removal efficiency. Typical removal rates, as reported by Schueler (1997a) are:

Total Suspended Solids: 67%
Total Phosphorous: 48%
Total Nitrogen: 31%
Nitrate Nitrogen: 24%
Metals: 24–73%
Bacteria: 65%

Table 2. Wet pond percent removal efficiency data

Wet Pond Removal Efficiencies							
Study	**TSS**	**TP**	**TN**	**NO_3**	**Metals**	**Bacteria**	**Practice Type**
City of Austin, TX 1991. Woodhollow, TX	54	46	39	45	69–76	46	wet pond
Driscoll 1983. Westleigh, MD	81	54	37	-	26–82	-	wet pond
Dorman et al., 1989. West Pond, MN	65	25	-	61	44–66	-	wet pond
Driscoll, 1983. Waverly Hills, MI	91	79	62	66	57–95	-	wet pond
Driscoll, 1983. Unqua, NY	60	45	-	-	80	86	wet pond
Cullum, 1985. Timber Creek, FL	64	60	15	80	-	-	wet pond
City of Austin, TX 1996. St. Elmo, TX.	92	80	19	-17	2–58	89-91	wet pond
Horner, Guedry, and Kortenhoff, 1990. SR 204, WA	99	91	-	-	88–90	-	wet pond
Horner, Guedry, and Kortenhoff, 1990. Seattle, WA	86.7	78.4	-	-	65–67	-	wet pond
Kantrowitz and Woodham, 1995. Saint Joe's Creek, FL	45	45	-	36	38–82	-	wet pond
Wu, 1989. Runaway Bay, NC	62	36	-	-	32–52	-	wet pond
Driscoll 1983. Pitt-AA, MI	32	18	-	7	13–62	-	wet pond
Bannerman and Dodds, 1992. Monroe Street, WI	90	65	-	-	65–75	70	wet pond
Horner, Guedry, and Kortenhoff, 1990. Mercer, WA	75	67	-	-	23–51	-	wet pond
Oberts, Wotzka, and Hartsoe 1989. McKnight, MN	85	48	30	24	67	-	wet pond
Yousef, Wanielista, and Harper 1986. Maitland, FL	-	-	-	87	77–96	-	wet pond
Wu, 1989. Lakeside Pond,	93	45	-	-	80–87	-	wet pond

NC							
Oberts, Wotzka, and Hartsoe, 1989. Lake Ridge, MN	90	61	41	10	73	-	wet pond
Driscoll, 1983. Lake Ellyn, IL	84	34	-	-	71-78	-	wet pond
Dorman et al., 1989. I-4, FL	54	69	-	97	47–74	-	wet pond
Martin, 1988. Highway Site, FL	83	37	30	28	50–77	-	wet pond
Driscoll, 1983. Grace Street, MI	32	12	6	-1	26	-	wet pond
Occoquan Watershed Monitoring Laboratory, 1983. Farm Pond, VA	85	86	34	-	-	-	wet pond
Occoquan Watershed Monitoring Laboratory, 1983. Burke, VA	-33.3	39	32	-	38–84	-	wet pond
Dorman et al., 1989. Buckland, CT	61	45	-	22	-25 to -51	-	wet pond
Holler, 1989. Boynton Beach Mall, FL	91	76	-	87	-	-	wet pond
Urbonas, Carlson, and Vang 1994. Shop Creek, CO	78	49	-12	-85	51–57	-	wet pond
Oberts and Wotzka, 1988. McCarrons, MN	91	78	85	-	90	-	wet pond
Gain, 1996. FL	54	30	16	24	42–73	-	wet pond
Ontario Ministry of the Environment, 1991. Uplands, Ontario	82	69	-	-	-	97	wet extended detention pond
Borden et al., 1996. Piedmont, NC	19.6	36.5	35.1	65.9	-4 to-97	-6	wet extended detention pond
Holler, 1990. Lake Tohopekaliga District, FL	-	85	-	-	-	-	wet extended detention pond
Ontario Ministry of the Environment 1991. Kennedy-Burnett, Ontario	98	79	54	-	21–39	99	wet extended detention pond
Ontario Ministry of the Environment 1991. East	52	47	-	-	-	56	wet extended

Barrhaven, Ontario							detention pond
Borden et al., 1996. Davis, NC	60.4	46.2	16	18.2	15–51	48	wet extended detention pond

There is considerable variability in the effectiveness of ponds, and it is believed that properly designing and maintaining ponds may help to improve their performance. The siting and design criteria presented in this sheet reflect the best current information and experience to improve the performance of wet ponds. A recent joint project of the American Society of Civil Engineers (ASCE) and the USEPA Office of Water may help to isolate specific design features that can improve performance. The National Stormwater Best Management Practice (BMP) database is a compilation of storm water practices which includes both design information and performance data for various practices. As the database expands, inferences about the extent to which specific design criteria influence pollutant removal may be made. More information on this database is available from the BMP database web page at *www.bmpdatabase.org*.

INFILTRATION BASIN

Description

An infiltration basin is a shallow impoundment which is designed to infiltrate storm water into the ground water. This practice is believed to have a high pollutant removal efficiency and can also help recharge the ground water, thus restoring low flows to stream systems. Infiltration basins can be challenging to apply on many sites, however, because of soils requirements. In addition, some studies have shown relatively high failure rates compared with other management practices.

Applicability

Infiltration basins have select applications. Their use is often sharply restricted by concerns over ground water contamination, soils, and clogging at the site.

Regional Applicability

Infiltration basins can be utilized in most regions of the country, with some design modifications in cold and arid climates. In regions of karst (i.e., limestone) topography, these storm water management practices may not be applied due to concerns of sink hole formation and ground water contamination.

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface exists. In these areas, few storm water practices can be easily applied due to space limitations. Infiltration basins can rarely be applied in the ultra-urban environment.

Two features that can restrict their use are the potential of infiltrated water to interfere with existing infrastructure, and the relatively poor infiltration capacity of most urban soils. In addition, while they consume only the space of the infiltration basin site itself, they need a continuous, relatively flat area. Thus, it is more difficult to fit them into small unusable areas on a site.

Storm Water Hot Spots

A storm water hot spot is an area where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. Infiltration basins should never receive runoff from storm water hot spots, unless the storm water has already been treated by another practice. This caution is due to potential ground water contamination.

Storm Water Retrofit

A storm water retrofit is a storm water practice (usually structural) put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Infiltration basins have limited applications as a storm water retrofit. Their use is restricted by three factors. First, infiltration basins should be used to treat small sites (less than 5 acres). Practices that are applied to small sites, such as infiltration basins, are generally a high-cost retrofit option in terms of construction cost and the maintenance burden associated with the large number of practices needed to retrofit a watershed. Second, it is often difficult to find areas where soils are appropriate for infiltration in an already urban or suburban environment. Finally, infiltration basins are best applied to small sites, yet need a flat, relatively continuous area. It is often difficult to find sites with this type of area available.

Cold Water (Trout) Streams

Infiltration basins are an excellent option for cold water streams because they encourage infiltration of storm water and maintain dry weather flow. Because storm water travels underground to the stream, it has little opportunity to increase in temperature.

Siting and Design Considerations

When designing infiltration basins, designers need to carefully consider both the restrictions on the site and design features to improve the long-term performance of the practice.

Siting Considerations

Infiltration practices need to be located extremely carefully. In particular, designers need to ensure that the soils on the site are appropriate for infiltration, and that designs minimize the potential for ground water contamination and long-term maintenance problems.

<u>Drainage Area</u>

Infiltration basins have historically been used as regional facilities, serving for both quantity and quality control. In some regions of the country, this practice is feasible, particularly if the soils are particularly sandy. In most areas, however, infiltration basins experience high rates of failure when used in this manner. In general, the practice is best applied to relatively small drainage areas (i.e., less than 10 acres).

<u>Slope</u>

The bottom of infiltration basins needs to be completely flat to allow infiltration throughout the entire basin bottom.

<u>Soils/Topography</u>

Soils and topography are strongly limiting factors when locating infiltration practices. Soils must be significantly permeable to ensure that the practice can infiltrate quickly enough to reduce the potential for clogging, and soils that infiltrate too rapidly may not provide sufficient treatment, creating the potential for ground water contamination. The infiltration rate should range between 0.5 and 3 inches per hour. In addition, the soils should have no greater than 20 percent clay content, and less than 40 percent silt/clay content (MDE, 2000). Finally, infiltration basins may not be used in regions of karst topography, due to the potential for sinkhole formation or ground water contamination.

<u>Ground Water</u>

Designers always need to provide significant separation distance (2 to 5 feet) from the bottom of the infiltration basin and the seasonally high ground water table, to reduce the risk of contamination. Infiltration practices should also be separated from drinking water wells.

Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. There are some features, however, that should be incorporated into most infiltration basin designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

<u>Pretreatment</u>

Pretreatment refers to design features that provide settling of large particles before runoff reaches a management practice, easing the long-term maintenance burden. Pretreatment is important for all structural management practices, but it is particularly important for infiltration practices. In order to ensure that pretreatment mechanisms are effective, designers should incorporate "multiple pretreatment," using practices such as grassed swales, sediment basins, and vegetated filter strips in series.

<u>Treatment</u>

Treatment design features enhance the pollutant removal of a practice. For infiltration practices, designers need to stabilize upland soils to ensure that the basin does not become clogged with sediment. In addition, the facility needs to be sized so that the volume of water to be treated infiltrates through the bottom in a given amount of time. Because infiltration basins are designed in this manner, infiltration basins designed on less permeable soils should be significantly larger than those designed on more permeable soils.

Conveyance

Storm water needs to be conveyed through storm water management practices safely and in a way that minimizes erosion. Designers need to be particularly careful in ensuring that channels leading to an infiltration practice are designed to minimize erosion. In general, infiltration basins should be designed to treat only small storms (i.e., only for water quality). Thus, these practices should be designed "off-line," using a flow separator to divert only small flows to the practice.

Maintenance Reduction

In addition to regular maintenance activities, designers also need to incorporate features into the design to ensure that the maintenance burden of a practice is reduced. These features can make regular maintenance activities easier or reduce the need to perform maintenance. In infiltration basins, designers need to provide access to the basin for regular maintenance activities. Where possible, a means to drain the basin, such as an underdrain, should be provided in case the bottom becomes clogged. This feature allows the basin to be drained and accessed for maintenance in the event that the water has ponded in the basin bottom or the soil is saturated.

Landscaping

Landscaping can enhance the aesthetic value of storm water practices or improve their function. In infiltration basins, the most important purpose of vegetation is to reduce the tendency of the practice to clog. Upland drainage needs to be properly stabilized with a thick layer of vegetation, particularly immediately following construction. In addition, providing a thick turf at the basin bottom helps encourage infiltration and prevent the formation of rills in the basin bottom.

Design Variations

Some modifications may be needed to ensure the performance of infiltration basins in arid and cold climates.

Arid or Semi-Arid Climates

In arid regions, infiltration practices are often highly recommended because of the need to recharge the ground water. In arid regions, designers need to emphasize pretreatment even more strongly to ensure that the practice does not clog, because of the high sediment concentrations associated with storm water runoff in areas such as the Southwest. In addition, the basin bottom may be planted with drought-tolerant species and/or covered with an alternative material such as sand or gravel.

Cold Climates

In extremely cold climates (i.e., regions that experience permafrost), infiltration basins may be an infeasible option. In most cold climates, infiltration basins can be a feasible practice, but there are some challenges to its use. First, the practice may become inoperable during some portions of the year when the surface of the basin becomes frozen. Other design features also may be incorporated to deal with the challenges of cold climates. One such challenge is the volume of runoff associated with the spring snowmelt event. The capacity of the infiltration basin might be increased to account for snowmelt volume.

Another option is the use of a seasonably operated facility (Oberts, 1994). A seasonally operated infiltration/detention basin combines several techniques to improve the performance of infiltration practices in cold climates. Two features, the underdrain system and level control valves, are useful in cold climates. These features are used as follows: At the beginning of the winter season, the level control valve is opened and the soil is drained. As the snow begins to melt in the spring, the underdrain and the level control valves are closed. The snowmelt is infiltrated until the capacity of the soil is reached. Then, the facility acts as a detention facility, providing storage for particles to settle.

Other design features can help to minimize problems associated with winter conditions, particularly concerns that chlorides from road salting may contaminate ground water. The basin may be disconnected during the winter to ensure that chlorides do not enter the ground water in areas where this is a problem, or if the basin is used to treat roadside runoff. Designers may also want to reconsider application of infiltration practices on parking lots or roads where deicing is used, unless it is confirmed that the practice will not cause elevated chloride levels in the ground water. If the basin is used for snow storage, or to treat roadside or parking lot runoff, the basin bottom should be planted with salt-tolerant vegetation.

Limitations
Although infiltration basins can be useful practices, they have several limitations. Infiltration basins are not generally aesthetic practices, particularly if they clog. If they clog, the soils become saturated, and the practice can be a source of mosquitoes. In addition, these practices are challenging to apply because of concerns over ground water contamination and sufficient soil infiltration. Finally, maintenance of infiltration practices can be burdensome, and they have a relatively high rate of failure.
Maintenance Considerations
Regular maintenance is critical to the successful operation of infiltration basins (see Table 1). Historically, infiltration basins have had a poor track record. In one study conducted in Prince George's County, Maryland (Galli, 1992), all of the infiltration basins investigated clogged within 2 years. This trend may not be the same in soils with high infiltration rates, however. A study of 23 infiltration basins in the Pacific Northwest showed better long-term performance in an area with highly permeable soils (Hilding, 1996). In this study, few of the infiltration basins had failed after 10 years.

Table 1. Typical maintenance activities for infiltration basins (Source: Modified from WMI, 1997)

Activity	**Schedule**
• Inspect facility for signs of wetness or damage to structures • Note eroded areas. • If dead or dying grass on the bottom is observed, check to ensure that water percolates 2–3 days following storms. • Note signs of petroleum hydrocarbon contamination and handle properly.	Semi-annual inspection
• Mow and remove litter and debris. • Stabilize of eroded banks. • Repair undercut and eroded areas at inflow and outflow structures.	Standard maintenance (as needed)
• Disc or otherwise aerate bottom. • Dethatch basin bottom.	Annual maintenance
• Scrape bottom and remove sediment. Restore original cross-section and infiltration rate. • Seed or sod to restore ground cover.	5-year maintenance

Effectiveness
Structural management practices can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. Infiltration basins can provide ground water recharge and pollutant removal.
Ground Water Recharge
Infiltration basins recharge the ground water because runoff is treated for water quality by filtering through the soil and discharging to ground water.
Pollutant Removal
Very little data are available regarding the pollutant removal associated with infiltration basins. It is generally assumed that they have very high pollutant removal because none of the storm water entering the practice remains on the surface. Schueler (1987) estimated pollutant removal for infiltration basins based on data from land disposal of wastewater. The average pollutant removal, assuming the infiltration basin is sized to treat the runoff from a 1-inch storm, is:
TSS 75%
Phosphorous 60–70%
Nitrogen 55–60%

Metals 85–90%
Bacteria 90%
These removal efficiencies assume that the infiltration basin is well designed and maintained. The information in the Siting and Design Considerations and Maintenance Considerations sections represent the best available information on how to properly design these practices. The design references below also provide additional information.

INFILTRATION TRENCH

Description

An infiltration trench (a.k.a. infiltration galley) is a rock-filled trench with no outlet that receives storm water runoff. Storm water runoff passes through some combination of pretreatment measures, such as a swale and detention basin, and into the trench. There, runoff is stored in the void space between the stones and infiltrates through the bottom and into the soil matrix. The primary pollutant removal mechanism of this practice is filtering through the soil.

Applicability

Infiltration trenches have select applications. While they can be applied in most regions of the country, their use is sharply restricted by concerns due to common site factors, such as potential ground water contamination, soils, and clogging.

Regional Applicability

Infiltration trenches can be utilized in most regions of the country, with some design modifications in cold and arid climates. In regions of karst (i.e., limestone) topography, these storm water management practices may not be applied due to concerns of sink hole formation and ground water contamination.

Ultra-Urban Areas

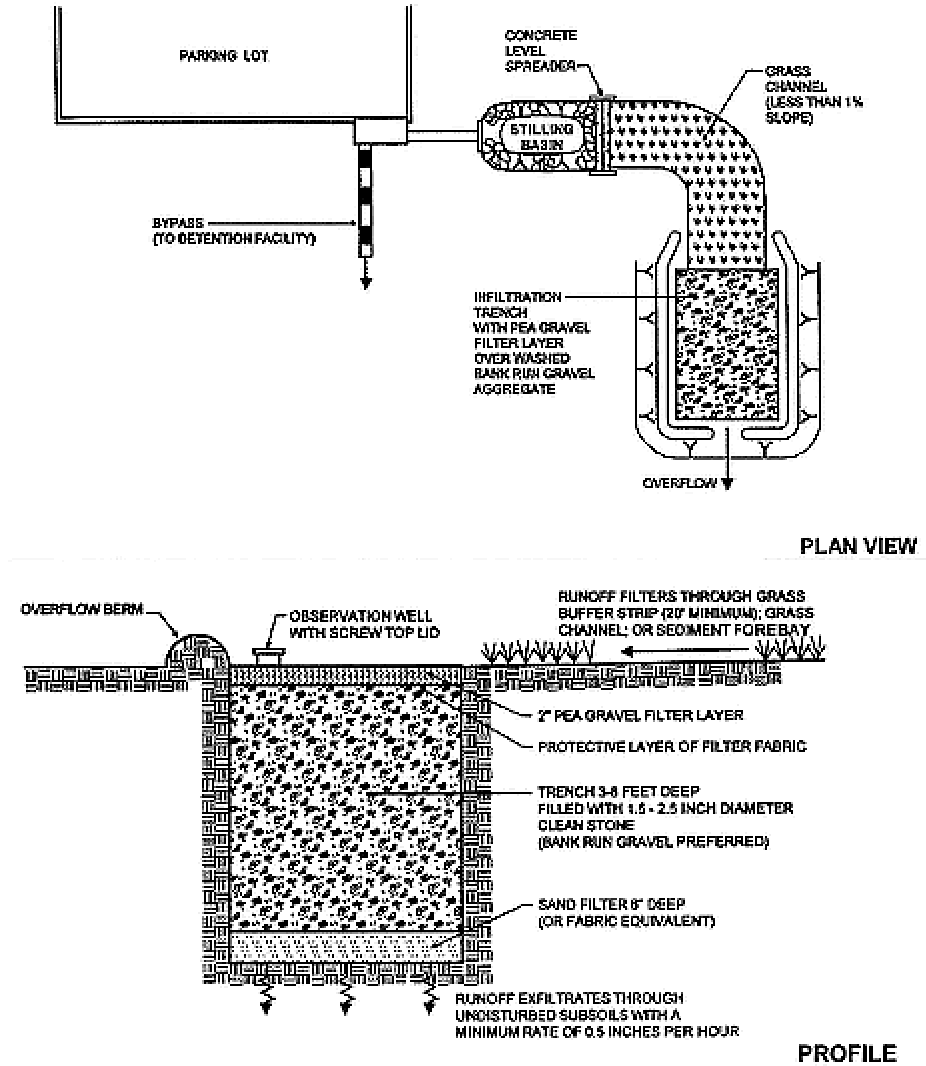
Ultra-urban areas are densely developed urban areas in which little pervious surface exists. Infiltration trenches can sometimes be applied in the ultra-urban environment. Two features that can restrict their use are the potential of infiltrated water to interfere with existing infrastructure, and the relatively poor infiltration of most urban soils.

Storm Water Hot Spots

Storm water hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. Infiltration trenches should not receive runoff from storm water hot spots, unless the storm water has already been treated by another storm water management practice, because of potential ground water contamination.

Siting and Design Considerations

Infiltration trenches have select applications. Although they can be applied in a variety of situations, the use of infiltration trenches is restricted by concerns over ground water contamination, soils, and clogging.



A schematic of an infiltration trench (Source: MDE, 2000)

Siting Considerations

Infiltration practices need to be sited extremely carefully. In particular, designers need to ensure that the soils on site are appropriate for infiltration and that designs minimize the potential for ground water contamination and long-term maintenance.

<u>Drainage Area</u>

Infiltration trenches generally can be applied to relatively small sites (less than 5 acres), with relatively high impervious cover. Application to larger sites generally causes clogging, resulting in a high maintenance burden.

<u>Slope</u>

Infiltration trenches should be placed on flat ground, but the slopes of the site draining to the practice can be as steep as 15 percent.

<u>Soils/Topography</u>

Soils and topography are strongly limiting factors when locating infiltration practices. Soils must be significantly permeable to ensure that the storm water can infiltrate quickly enough to reduce the potential for clogging. In addition, soils that infiltrate too rapidly may not provide sufficient treatment, creating the potential for ground water contamination. The infiltration rate should range between 0.5 and 3 inches per hour. In addition, the soils should have no greater than 20-percent clay content, and less than 40-percent silt/clay content (MDE, 2000). The infiltration rate and textural class of the soil need to be confirmed in the field; designers should not rely on more generic information such as a soil survey. Finally, infiltration trenches may not be used in regions of karst topography, due to the potential for sinkhole formation or ground water contamination.

Ground Water

Designers always need to provide significant separation (2 to 5 feet) from the bottom of the infiltration trench and the seasonally high ground water table, to reduce the risk of contamination. In addition, infiltration practices should be separated from drinking water wells.

Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. There are some features, however, that should be incorporated into most infiltration trench designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

Pretreatment

Pretreatment refers to design features that provide settling of large particles before runoff reaches a management practice, easing the long-term maintenance burden. Pretreatment is important for all structural storm water management practices, but it is particularly important for infiltration practices. To ensure that pretreatment mechanisms are effective, designers should incorporate "multiple pretreatment," using practices such as grassed swales, vegetated filter strips, detention, or a plunge pool in series.

Treatment

Treatment design features enhance the pollutant removal of a practice. During the construction process, the upland soils of infiltration trenches need to be stabilized to ensure that the trench does not become clogged with sediment. Furthermore, the practice should be filled with large clean stones that can retain the volume of water to be treated in their voids. Like infiltration basins, this practice should be sized so that the volume to be treated can infiltrate out of the trench bottom in 24 hours.

Conveyance

Storm water needs to be conveyed through storm water management practices safely, and in a way that minimizes erosion. Designers need to be particularly careful in ensuring that channels leading to an infiltration practice are designed to minimize erosion. Infiltration trenches should be designed to treat only small storms, (i.e., only for water quality). Thus, these practices should be designed "off-line," using a structure to divert only small flows to the practice. Finally, the sides of an infiltration trench should be lined with a geotextile fabric to prevent flow from causing rills along the edge of the practice.

Maintenance Reduction

In addition to regular maintenance activities, designers also need to incorporate features into the design to ensure that the maintenance burden of a practice is reduced. These features can make regular maintenance activities easier or reduce the need to perform maintenance. As with all management practices, infiltration trenches should have an access path for maintenance activities. An observation well (i.e., a perforated PVC pipe that leads to the bottom of the trench) can enable inspectors to monitor the drawdown rate. Where possible, trenches should have a means to drain the practice if it becomes clogged, such as an underdrain. An underdrain is a perforated pipe system in a gravel bed, installed on the bottom of filtering practices to collect and remove filtered runoff. An underdrain pipe with a shutoff valve can be used in an infiltration system to act as an overflow in case of clogging.

Landscaping

In infiltration trenches, there is no landscaping on the practice itself, but it is important to ensure that the upland drainage is properly stabilized with thick vegetation, particularly following construction.

Regional Variations

Arid or Semi-Arid Climates

In arid regions, infiltration practices are often highly recommended because of the need to recharge the ground water. One concern in these regions is the potential of these practices to clog, due to relatively high sediment concentrations in these environments. Pretreatment needs to be more heavily emphasized in these dryer climates.

Cold Climates

In extremely cold climates (i.e., regions that experience permafrost), infiltration trenches may be an infeasible option. In most cold climates, infiltration trenches can be a feasible management practice, but there are some challenges to their use. The volume may need to be increased in order to treat snowmelt. In addition, if the practice is used to treat roadside runoff, it may be desirable to divert flow around the trench in the winter to prevent infiltration of chlorides from road salting, where this is a problem. Finally, a minimum setback from roads is needed to ensure that the practice does not cause frost heaving.

Limitations

Although infiltration trenches can be a useful management practice, they have several limitations. While they do not detract visually from a site, infiltration trenches provide no visual enhancements. Their application is limited due to concerns over ground water contamination and other soils requirements. Finally, maintenance can be burdensome, and infiltration practices have a relatively high rate of failure.

Maintenance Considerations

In addition to incorporating features into the design to minimize maintenance, some regular maintenance and inspection practices are needed. Table 1 outlines some of these practices.

Table 1. Typical maintenance activities for infiltration trenches (Source: Modified from WMI, 1997)

Activity	Schedule
• Check observation wells following 3 days of dry weather. Failure to percolate within this time period indicates clogging. • Inspect pretreatment devices and diversion structures for sediment build-up and structural damage.	Semi-annual inspection
• Remove sediment and oil/grease from pretreatment devices and overflow structures.	Standard maintenance
• If bypass capability is available, it may be possible to regain the infiltration rate in the short term by using measures such as providing an extended dry period.	5-year maintenance
• Total rehabilitation of the trench should be conducted to maintain storage capacity within 2/3 of the design treatment volume and 72-hour exfiltration rate limit. • Trench walls should be excavated to expose clean soil.	Upon failure

Infiltration practices have historically had a high rate of failure compared to other storm water management practices. One study conducted in Prince George's County, Maryland (Galli, 1992), revealed that less than half of the infiltration trenches investigated (of about 50) were still functioning properly, and less than one-third still functioned properly after 5 years. Many of these practices, however, did not incorporate advanced pretreatment. By carefully selecting the location and improving the design features of infiltration practices, their performance should improve.

Effectiveness

Structural storm water management practices can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. Infiltration trenches can provide ground water recharge, pollutant control, and can help somewhat to provide channel protection.

Ground Water Recharge

Infiltration trenches recharge the ground water because runoff is treated for water quality by filtering through the soil and discharging to ground water.

Pollutant Removal
Very little data are available regarding the pollutant removal associated with infiltration trenches. It is generally assumed that they have very high pollutant removal, because none of the storm water entering the practice remains on the surface. Schueler (1987) estimated pollutant removal for infiltration trenches based on data from land disposal of wastewater. The average pollutant removal, assuming the infiltration trench is sized to treat the runoff from a 1-inch storm, is:
TSS 75%
Phosphorous 60–70%
Nitrogen 55–60%
Metals 85–90%
Bacteria 90%
These removal efficiencies assume that the infiltration trench is well designed and maintained. The information in the Siting and Design Considerations and Maintenance Considerations sections represent the best available information on how to properly design these practices. The design references below provide additional information.

POROUS PAVEMENT

Description
Porous pavement is a permeable pavement surface with an underlying stone reservoir to temporarily store surface runoff before it infiltrates into the subsoil. This porous surface replaces traditional pavement, allowing parking lot storm water to infiltrate directly and receive water quality treatment. There are a few porous pavement options, including porous asphalt, pervious concrete, and grass pavers. Porous asphalt and pervious concrete appear to be the same as traditional pavement from the surface, but are manufactured without "fine" materials, and incorporate void spaces to allow infiltration. Grass pavers are concrete interlocking blocks or synthetic fibrous gridded systems with open areas designed to allow grass to grow within the void areas. Other alternative paving surfaces can help reduce the runoff from paved areas but do not incorporate the stone trench for temporary storage below the pavement (see Green Parking fact sheet). While porous pavement has the potential to be a highly effective treatment practice, maintenance has been a concern in past applications of the practice.

Application
The ideal application for porous pavement is to treat low-traffic or overflow parking areas. Porous pavement may also have some application on highways, where it is currently used as a surface material to reduce hydroplaning.

Regional Applicability
Porous pavement can be applied in most regions of the country, but the practice has unique challenges in cold climates. Porous pavement cannot be used where sand is applied to the pavement surface because the sand will clog the surface of the material. Care also needs to be taken when applying salt to a porous pavement surface as chlorides from road salt may migrate into the ground water. For block pavers, plowing may be challenging because the edge of the snow plow blade can catch the edge of the blocks, damaging the surface. This difficulty does not imply that it is impossible to use porous pavement in cold climates. Another concern in cold climates is that infiltrating runoff below pavement may cause frost heave, although design modifications can reduce this risk. Porous pavement has been used successfully in Norway (Stenmark, 1995), incorporating design features to reduce frost heave. Furthermore, some experience suggests that snow melts faster on a porous surface because of rapid drainage below the snow surface (Cahill Associates, 1993).

Ultra-Urban Areas
Ultra-urban areas are densely developed urban areas in which little pervious surface exists. Porous pavements are a good option in these areas because they consume no space. They are not ideal for high-traffic areas, however, because of the potential for failure due to clogging (Galli, 1992).

Storm Water Hot Spots
Storm water hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. These areas include

commercial nurseries, auto recycle facilities, commercial parking lots, fueling stations, storage areas, industrial rooftops, marinas, outdoor container storage of liquids, outdoor loading/unloading facilities, public works storage areas, hazardous materials generators (if containers are exposed to rainfall), vehicle service and maintenance areas, and vehicle and equipment washing/steam cleaning facilities. Since porous pavement is an infiltration practice, it should not be applied on storm water hot spots due to the potential for ground water contamination.

Storm Water Retrofit

A storm water retrofit is a storm water management practice (usually structural) put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Since porous pavement can only be applied to relatively small sites, using porous pavement as a primary tool for watershed retrofitting would be expensive. The best application of porous pavement for retrofits is on individual sites where a parking lot is being resurfaced.

Cold Water (Trout) Streams

Porous pavement can help to reduce the increased temperature commonly associated with increased impervious cover. Storm water ponds on the surface of conventional pavement, and is subsequently heated by the sun and hot pavement surface. By rapidly infiltrating rainfall, porous pavement reduces the time that storm water is exposed to the sun and heat.

Siting and Design Considerations

Siting Considerations

Porous pavement has the same siting considerations as other infiltration practices (see Infiltration Trench fact sheet). The site needs to meet the following criteria:

- Soils need to have a permeability between 0.5 and 3.0 inches per hour.
- The bottom of the stone reservoir should be completely flat so that infiltrated runoff will be able to infiltrate through the entire surface.
- Porous pavement should be sited at least 2 to 5 feet above the seasonally high ground water table, and at least 100 feet away from drinking water wells.
- Porous pavement should be sited on low-traffic or overflow parking areas, which are not sanded for snow removal.

Design Considerations

Some basic features should be incorporated into all porous pavement practices. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

1. *Pretreatment*. In porous pavement designs, the pavement itself acts as pretreatment to the stone reservoir below. Because the surface serves this purpose, frequent maintenance of the surface is critical to prevent clogging. Another pretreatment item can be the incorporation of a fine gravel layer above the coarse gravel treatment reservoir. Both of these pretreatment measures are marginal, which is one reason that these systems have a high failure rate.
2. *Treatment*. The stone reservoir below the pavement surface should be composed of layers of small stone directly below the pavement surface, and the stone bed below the permeable surface should be sized to attenuate storm flows for the storm event to be treated. Typically, porous pavement is sized to treat a small event, such as a water quality storm (i.e., the storm that will be treated for pollutant removal), which can range from 0.5 to 1.5 inches. As in infiltration trenches, water can be stored only in the void spaces of the stone reservoir.
3. *Conveyance*. Water is conveyed to the stone reservoir through the surface of the pavement and infiltrates into the ground through the bottom of this stone reservoir. A geosynthetic liner and sand layer should be placed below the stone reservoir to prevent preferential flow paths and to maintain a flat bottom. Designs also need some method to convey larger storms to the storm drain system. One option is to use storm drain inlets set slightly above the elevation of the pavement. This would allow for some ponding above the surface, but would bypass flows that are too large to be treated by the system or when the surface clogs.

4. *Maintenance Reduction*. One nonstructural component that can help ensure proper maintenance of porous pavement is the use of a carefully worded maintenance agreement that provides specific guidance, including how to conduct routine maintenance and how the surface should be repaved. Ideally, signs should be posted on the site identifying porous pavement areas.

   One design option incorporates an "overflow edge," which is a trench surrounding the edge of the pavement. The trench connects to the stone reservoir below the surface of the pavement. Although this feature does not in itself reduce maintenance requirements, it acts as a backup in case the surface clogs. If the surface clogs, storm water will flow over the surface and into the trench, where some infiltration and treatment will occur.
5. *Landscaping*. For porous pavement, the most important landscaping feature is a fully stabilized upland drainage. Reducing sediment loads entering the pavement can help to prevent clogging.

Design Variations

In one design variation, the stone reservoir below the filter can also treat runoff from other sources such as rooftop runoff. In this design, pipes are connected to the stone reservoir to direct flow throughout the bottom of the storage reservoir (Cahill Associates, 1993; Schueler, 1987). If used to treat off-site runoff, porous pavement should incorporate pretreatment, as with all structural management practices.

Regional Adaptations

In cold climates, the base of the stone reservoir should be below the frost line. This modification will help to reduce the risk of frost heave.

Limitations

In addition to the relatively strict siting requirements of porous pavement, a major limitation to the practice is the poor success rate it has experienced in the field. Several studies indicate that, with proper maintenance, porous pavement can retain its permeability (e.g., Goforth et al., 1983; Gburek and Urban, 1980; Hossain and Scofield, 1991). When porous pavement has been implemented in communities, however, the failure rate has been as high as 75 percent over 2 years (Galli, 1992).

Maintenance Considerations

Porous pavement requires extensive maintenance compared with other practices. In addition to owners not being aware of porous pavement on a site, not performing these maintenance activities is the chief reason for failure of this practice. Typical requirements are shown in Table 1.

Table 1. Typical maintenance activities for porous pavement (Source: WMI, 1997)

Activity	**Schedule**
• Avoid sealing or repaving with non-porous materials.	N/A
• Ensure that paving area is clean of debris. • Ensure that paving dewaters between storms. • Ensure that the area is clean of sediments.	Monthly
• Mow upland and adjacent areas, and seed bare areas. • Vacuum sweep frequently to keep the surface free of sediment.	As needed (typically three to four times per year).
• Inspect the surface for deterioration or spalling.	Annual

Effectiveness

Porous pavement can be used to provide ground water recharge and to reduce pollutants in storm water runoff. Some data suggest that as much as 70 to 80 percent of annual rainfall will go toward ground water recharge (Gburek and Urban, 1980). These data will vary depending on design characteristics and underlying

soils. Two studies have been conducted on the long-term pollutant removal of porous pavement, both in the Washington, DC, area. They suggest high pollutant removal, although it is difficult to extrapolate these results to all applications of the practice. The results of the studies are presented in Table 2.
Table 2. Effectiveness of porous pavement pollutant removal (Schueler, 1987)

	Pollutant Removal (%)				
Study	**TSS**	**TP**	**TN**	**COD**	**Metals**
Prince William, VA	82	65	80	-	-
Rockville, MD	95	65	85	82	98–99

BIORETENTION

Description

Bioretention areas are landscaping features adapted to provide on-site treatment of storm water runoff. They are commonly located in parking lot islands or within small pockets of residential land uses. Surface runoff is directed into shallow, landscaped depressions. These depressions are designed to incorporate many of the pollutant removal mechanisms that operate in forested ecosystems. During storms, runoff ponds above the mulch and soil in the system. Runoff from larger storms is generally diverted past the facility to the storm drain system. The remaining runoff filters through the mulch and prepared soil mix. Typically, the filtered runoff is collected in a perforated underdrain and returned to the storm drain system.

Applicability

Bioretention systems are generally applied to small sites and in a highly urbanized setting. Bioretention can be applied in many climatological and geologic situations, with some minor design modifications.

Regional Applicability

Bioretention systems are applicable almost everywhere in the United States. In arid or cold climates, however, some minor design modifications may be needed.

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface exists. Bioretention facilities are ideally suited to many ultra-urban areas, such as parking lots. While they consume a fairly large amount of space (approximately 5 percent of the area that drains to them), they can be fit into existing parking lot islands or other landscaped areas.

Storm Water Hot Spots

Storm water hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. A typical example is a gas station or convenience store parking lot. Bioretention areas can be used to treat storm water hot spots as long as an impermeable liner is used at the bottom of the filter bed.

Storm Water Retrofit

A storm water retrofit is a storm water management practice (usually structural) put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Bioretention can be used as a storm water retrofit, by modifying existing landscaped areas, or if a parking lot is being resurfaced. In highly urbanized areas, this is one of the few retrofit options that can be employed. However, it is very expensive to retrofit an entire watershed or subwatershed using storm water management practices designed to treat small sites.

Cold Water (Trout) Streams

Some species in cold water streams, notably trout, are extremely sensitive to changes in temperature. In order to protect these resources, designers should avoid treatment practices that increase the temperature of the storm water runoff they treat. Bioretention is a good option in cold water streams because water ponds in them for only a short time, decreasing the potential for stream warming.

Siting and Design Considerations
In addition to the broad applicability concerns described above, designers need to consider conditions at the site level. In addition, they need to incorporate design features to improve the longevity and performance of the practice, while minimizing the maintenance burden.

Siting

Some considerations for selecting a storm water management practice are the drainage area the practice will need to treat, the slopes both at the location of the practice and the drainage area, soil and subsurface conditions, and the depth of the seasonably high ground water table. Bioretention can be applied on many sites, with its primary restriction being the need to apply the practice on small sites.

Drainage Area

Bioretention areas should usually be used on small sites (i.e., 5 acres or less). When used to treat larger areas, they tend to clog. In addition, it is difficult to convey flow from a large area to a bioretention area.

Slope

Bioretention areas are best applied to relatively shallow slopes (usually about 5 percent). However, sufficient slope is needed at the site to ensure that water that enters the bioretention area can be connected with the storm drain system. These storm water management practices are most often applied to parking lots or residential landscaped areas, which generally have shallow slopes.

Soils/Topography

Bioretention areas can be applied in almost any soils or topography, since runoff percolates through a man-made soil bed and is returned to the storm water system.

Ground Water

Bioretention should be separated somewhat from the ground water to ensure that the ground water table never intersects with the bed of the bioretention facility. This design consideration prevents possible ground water contamination.

Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. There are some features, however, that should be incorporated into most bioretention area designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

Pretreatment

Pretreatment refers to features of a management practice that cause coarse sediment particles and their associated pollutants to settle. Incorporating pretreatment helps to reduce the maintenance burden of bioretention and reduces the likelihood that the soil bed will clog over time. Several different mechanisms can be used to provide pretreatment in bioretention facilities. Often, runoff is directed to a grass channel or filter strip to filter out coarse materials before the runoff flows into the filter bed of the bioretention area. Other features may include a pea gravel diaphragm, which acts to spread flow evenly and drop out larger particles.

Treatment

Treatment design features help enhance the ability of a storm water management practice to remove pollutants. Several basic features should be incorporated into bioretention designs to enhance their pollutant removal. The bioretention system should be sized between 5 and 10 percent of the impervious area draining to it. The practice should be designed with a soil bed that is a sand/soil matrix, with a mulch layer above the soil bed. The bioretention area should be designed to pond a small amount of water (6–9 inches) above the filter bed.

Conveyance

Conveyance of storm water runoff into and through a storm water practice is a critical component of any storm water management practice. Storm water should be conveyed to and from practices safely and to minimize erosion potential. Ideally, some storm water treatment can be achieved during conveyance to and from the practice.

Bioretention practices are designed with an underdrain system to collect filtered runoff at the bottom of the filter bed and direct it to the storm drain system. An underdrain is a perforated pipe system in a gravel bed, installed on the bottom of the filter bed. Designers should provide an overflow structure to convey flow from storms that are not treated by the bioretention facility to the storm drain.

Maintenance Reduction

In addition to regular maintenance activities needed to maintain the function of storm water practices, some design features can be incorporated to reduce the required maintenance of a practice. Designers should ensure that the bioretention area is easily accessible for maintenance.

Landscaping

Landscaping is critical to the function and aesthetic value of bioretention areas. It is preferable to plant the area with native vegetation, or plants that provide habitat value, where possible. Another important design feature is to select species that can withstand the hydrologic regime they will experience. At the bottom of the bioretention facility, plants that tolerate both wet and dry conditions are preferable. At the edges, which will remain primarily dry, upland species will be the most resilient. Finally, it is best to select a combination of trees, shrubs, and herbaceous materials.

Design Variations

One design alternative to the traditional bioretention practice is the use of a "partial exfiltration" system, used to promote ground water recharge. Other design modifications may make this practice more effective in arid or cold climates.

Partial Exfiltration

In one design variation of the bioretention system, the underdrain is only installed on part of the bottom of the bioretention system. This design alternative allows for some infiltration, with the underdrain acting as more of an overflow. This system can be applied only when the soils and other characteristics are appropriate for infiltration (see Infiltration Trench and Infiltration Basin).

Arid Climates

In arid climates, bioretention areas should be landscaped with drought-tolerant species.

Cold Climates

In cold climates, bioretention areas can be used as snow storage areas. If used for this purpose, or if used to treat runoff from a parking lot where salt is used as a deicer, the bioretention area should be planted with salt-tolerant, nonwoody plant species.

Limitations

Bioretention areas have a few limitations. Bioretention areas cannot be used to treat a large drainage area, limiting their usefulness for some sites. In addition, although the practice does not consume a large amount of space, incorporating bioretention into a parking lot design may reduce the number of parking spaces available. Finally, the construction cost of bioretention areas is relatively high compared with many other management practices (see Cost Considerations).

Maintenance Considerations

Bioretention requires frequent landscaping maintenance, including measures to ensure that the area is functioning properly, as well as maintenance of the landscaping on the practice. In many cases, bioretention areas initially require intense maintenance, but less maintenance is needed over time. In many cases, maintenance tasks can be completed by a landscaping contractor, who may already be hired at the site.

Table 1. Typical maintenance activities for bioretention areas (Source: ETA and Biohabitats, 1993)

Activity	**Schedule**
• Remulch void areas • Treat diseased trees and shrubs • Mow turf areas	As needed
• Water plants daily for 2 weeks	At project completion
• Inspect soil and repair eroded areas	Monthly

• Remove litter and debris	
• Remove and replace dead and diseased vegetation	Twice per year
• Add mulch • Replace tree stakes and wires	Once per year

Effectiveness
Structural storm water management practices can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. In general, bioretention areas can provide only pollutant removal.

Flood Control
Bioretention areas are not designed to provide flood control. These larger flows must be diverted to a detention pond that can provide flood peak reduction.

Channel Protection
Bioretention areas are generally not designed to provide channel protection because at the scale at which they are typically installed they are not able to infiltrate large volumes. (They are typically designed to treat and infiltrate the first inch of runoff and are bypassed by larger flows that can erode channels.) Channel protection must be provided by other means, such as ponds or other volume control practices.

Ground Water Recharge
Bioretention areas do not usually recharge the ground water, except in the case of the partial exfiltration design (see Design Variations).

Pollutant Removal
Little pollutant removal data have been collected on the pollutant removal effectiveness of bioretention areas. A field and laboratory analysis of bioretention facilities conducted by Davis et al. (1997), showed very high removal rates (roughly 95 percent for copper, 98 percent for phosphorus, 20 percent for nitrate, and 50 percent for total Kjeldhal nitrogen (TKN). Table 2 shows data from two other studies of field bioretention sites in Maryland.

Table 2. Pollutant removal effectiveness of two bioretention areas in Maryland (USEPA, 2000).

Pollutant	**Pollutant Removal**
Copper	43%–97%
Lead	70%–95%
Zinc	64%–95%
Phosphorus	65%–87%
TKN	52–67%
NH_4^+	92%
NO_3^-	15%–16%
Total nitrogen (TN)	49%
Calcium	27%

Assuming that bioretention systems behave similarly to swales, their removal rates are relatively high. The negative removal rate for bacteria may reflect sampling errors, such as failure to account for bacterial sources in the practice. Alternatively, these data may be the result of bacteria reproduction in the moist soils of swale systems.

There is considerable variability in the effectiveness of bioretention areas, and it is believed that properly designing and maintaining these areas may help to improve their performance. The siting and design criteria presented in this sheet reflect the best current information and experience to improve the performance of bioretention areas. A recent joint project of the American Society of Civil Engineers (ASCE) and the EPA Office of Water may help to isolate specific design features that can improve performance. The National Stormwater Best Management Practice (BMP) database is a compilation of storm water practices which includes both design information and performance data for various practices. As the database expands, inferences about the extent to which specific design criteria influence pollutant removal might be made. More information on this database is accessible on the BMP database web page at http://www.bmpdatabase.org.

SAND AND ORGANIC FILTERS

Description

Sand filters are usually two-chambered storm water practices; the first is a settling chamber, and the second is a filter bed filled with sand or another filtering media. As storm water flows into the first chamber, large particles settle out, and then finer particles and other pollutants are removed as storm water flows through the filtering medium. There are several modifications of the basic sand filter design, including the surface sand filter, underground sand filter, perimeter sand filter, organic media filter, and Multi-Chamber Treatment Train. All of these filtering practices operate on the same basic principle. Modifications to the traditional surface sand filter were made primarily to fit sand filters into more challenging design sites (e.g., underground and perimeter filters) or to improve pollutant removal (e.g., organic media filter).

Applicability

Sand filters can be applied in most regions of the country and on most types of sites. Some restrictions at the site level, however, might restrict the use of sand filters as a storm water management practice (see Siting and Design Considerations).

Regional Applicability

Although sand filters can be used in both cold and arid climates, some design modifications might be necessary (See Siting and Design Considerations).

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface is present. Sand filters in general are good options in these areas because they consume little space. Underground and perimeter sand filters in particular are well suited to the ultra-urban setting because they consume no surface space.

Storm Water Hot Spots

Storm water hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. These areas include commercial nurseries, auto recycle facilities, commercial parking lots, fueling stations, storage areas, industrial rooftops, marinas, outdoor container storage of liquids, outdoor loading/unloading facilities, public works storage areas, hazardous materials generators (if containers are exposed to rainfall), vehicle service and maintenance areas, and vehicle and equipment washing/steam cleaning facilities. Sand filters are an excellent option to treat runoff from storm water hot spots because storm water treated by sand filters has no interaction with, and thus no potential to contaminate, the groundwater.

Storm Water Retrofit

A storm water retrofit is a storm water management practice (usually structural) put into place after development has occurred to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Sand filters are a good option to achieve water quality goals in retrofit studies where space is limited because they consume very little surface space and have few site restrictions. It is important to note, however, that sand filters cannot treat a very large drainage area. Using small-site BMPs in a retrofit may be the only option for a retrofit study in a highly urbanized area, but it is expensive to treat the drainage area of an entire watershed using many small-site practices, as opposed to one larger facility such as a pond.

Cold Water (Trout) Streams

Some species in cold water streams, notably trout, are extremely sensitive to changes in temperature. To protect these resources, designers should avoid treatment practices that increase the temperature of the storm water runoff they treat. Sand filters can be a good treatment option for cold water streams. In some storm water treatment practices, particularly wet ponds, runoff is warmed by the sun as it resides in the permanent pool. Surface sand filters are typically not designed with a permanent pool, although there is ponding in the sedimentation chamber and above the sand filter. Designers may consider shortening the detention time in cold water watersheds. Underground and perimeter sand filter designs have little potential for warming because these practices are not exposed to the sun.

Siting and Design Considerations

In addition to the broad applicability issues described above, designers need to consider conditions at the site level and need to incorporate design features to improve the longevity and performance of the practice, while minimizing the maintenance burden.

Siting Considerations

Some considerations when selecting a storm water management practice are the drainage area the practice will need to treat, the slopes both at the location of the practice and draining to it, soil and subsurface conditions, and the depth of the seasonably high ground water table. Although sand filters are relatively versatile, some site restrictions such as available head might limit their use.

<u>Drainage Area</u>

Sand filters are best applied on relatively small sites (up to 10 acres for surface sand filters and closer to 2 acres for perimeter or underground filters [MDE, 2000]). Filters have been used on larger drainage areas, of up to 100 acres, but these systems can clog when they treat larger drainage areas unless adequate measures are provided to prevent clogging, such as a larger sedimentation chamber or more intensive regular maintenance.

<u>Slope</u>

Sand filters can be used on sites with slopes up to about 6 percent. It is challenging to use most sand filters in very flat terrain because they require a significant amount of elevation drop, or head (about 5 to 8 feet), to allow flow through the system. One exception is the perimeter sand filter, which can be applied with as little as 2 feet of head.

<u>Soils/Topography</u>

When sand filters are designed as a stand-alone practice, they can be used on almost any soil because they can be designed so that storm water never infiltrates into the soil or interacts with the ground water. Alternatively, sand filters can be designed as pretreatment for an infiltration practice, where soils do play a role.

<u>Ground Water</u>

Designers should provide at least 2 feet of separation between the bottom of the filter and the seasonally high ground water table. This design feature prevents both structural damage to the filter and possibly, though unlikely, ground water contamination.

Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. Some features, however, should be incorporated into most designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

<u>Pretreatment</u>

Pretreatment is a critical component of any storm water management practice. In sand filters, pretreatment is achieved in the sedimentation chamber that precedes the filter bed. In this chamber, the coarsest particles settle out and thus do not reach the filter bed. Pretreatment reduces the maintenance burden of sand filters by reducing the potential of these sediments to clog the filter. Designers should provide at least 25 percent of the water quality volume in a dry or wet sedimentation chamber as pretreatment to the filter system. The water quality volume is the amount of runoff that will be treated for pollutant removal in the practice. Typical water quality volumes are the runoff from a 1-inch storm or ½ inch of runoff over the entire drainage area to the practice.

The area of the sedimentation chamber may be determined based on the Camp-Hazen equation, as adapted by the Washington State Department of Ecology (Washington State DOE, 1992). This equation can be expressed as:

$A_s = (Q_o/W)\mathit{ln}(1-E)$

where:

A_s = surface area (ft^2);

Q_o = discharge rate from basin (water quality volume/detention time);

W = particle settling velocity (ft/s);

[CWP (1996) used a settling of 0.0004 ft/s for drainage areas greater than 75% impervious and 0.0033 ft/s for drainage areas less than or equal to 75% impervious to account for the finer particles that erode from pervious surfaces.]

E = removal efficiency fraction (usually assumed to be about 0.9(90%)).

Using the simplifying assumption of a 24-hour detention time, CWP (1996) reduced the above equation to

A_s = 0.066WTV (>75%)

A_s = 0.0081WTV (< or = 75%)

where

WTV = water quality volume (ft^3), or the volume of storm water to be treated by the practice.

<u>Treatment</u>

Treatment design features help enhance the ability of a storm water management practice to remove pollutants. In filtering systems, designers should provide at least 75 percent of the water quality volume in the practice (including both the sand chamber and the sediment chamber). In sand filters, designers should select a medium sand as the filtering medium.

The filter bed should be sized using Darcy's Law, which relates the velocity of fluids to the hydraulic head and the coefficient of permeability of a medium. The resulting equation, as derived by the city of Austin, Texas, (1996), is

AF = WTV d/[k t (h+d)]

where

AF = area of the filter bed (ft^2);

d = depth of the filter bed (ft; usually about 1.5 feet, depending on the design);

k = coefficient of permeability of the filtering medium (ft/day);

t = time for the water quality volume to filter through the system (days; usually assumed to be 1.67 days); and

h = average water height above the sand bed (ft; assumed to be one-half of the maximum head).

Typical values for k, as assembled by CWP (1996), are shown in Table 1.

Table 1: Coefficient of permeability values for storm water filtering practices (CWP, 1996)

Filter Medium	**Coefficient of Permeability (ft/day)**
Sand	3.5
Peat/Sand	2.75
Compost	8.7

<u>Conveyance</u>

Conveyance of storm water runoff into and through a storm water practice is a critical component of any storm water management practice. Storm water should be conveyed to and from practices safely and in a manner that minimizes erosion potential. Ideally, some storm water treatment can be achieved during conveyance to and from the practice.

Typically, filtering practices are designed as "off-line" systems, meaning that they have the smaller water quality volume diverted to them only during larger storms, using a flow splitter, which is a structure that bypasses larger flows to the storm drain system or to a stabilized channel. One exception is the perimeter filter; in this design, all flows enter the system, but larger flows overflow to an outlet chamber and are not treated by the practice.

All filtering practices, with the exception of exfilter designs (see Design Variations) are designed with an under drain below the filtering bed. An under drain is a perforated pipe system in a gravel bed, installed on the bottom of filtering practices and used to collect and remove filtered runoff.

Maintenance Reduction

In addition to regular maintenance activities needed to maintain the function of storm water practices, some design features can be incorporated to ease the maintenance burden of each practice. Designers should provide maintenance access to filtering systems. In underground sand filters, confined space rules defined by the Occupational Safety and Health Administration (OSHA) need to be addressed.

Landscaping

Landscaping can add to both the aesthetic value and the treatment ability of storm water practices. In sand filters, little landscaping is generally used on the practice, although surface sand filters and organic media filters may be designed with a grass cover on the surface of the filter. In all filters, designers need to ensure that the contributing drainage has dense vegetation to reduce sediment loads to the practice.

Design Variations

As mentioned earlier in this fact sheet, there are five basic storm water filter designs--surface sand filter, underground filter, perimeter filter (also known as the "Delaware" filter), organic media filter, and Multi-Chamber Treatment Train. Other design variations can incorporate design features to recharge ground water or to meet the design challenges of cold or arid climates.

Surface Sand Filter

The surface sand filter is the original sand filter design. In this practice both the filter bed and the sediment chamber are aboveground. The surface sand filter is designed as an off-line practice, where only the water quality volume is directed to the filter. The surface sand filter is the least expensive filter option and has been the most widely used.

Underground Sand Filter

The underground sand filter is a modification of the surface sand filter, where all of the filter components are underground. Like the surface sand filter, this practice is an off-line system that receives only the smaller water quality events. Underground sand filters are expensive to construct but consume very little space. They are well suited to highly urbanized areas.

Perimeter Sand Filter

The perimeter sand filter also includes the basic design elements of a sediment chamber and a filter bed. In this design, however, flow enters the system through grates, usually at the edge of a parking lot. The perimeter sand filter is the only filtering option that is on-line, with all flows entering the system but larger events bypassing treatment by entering an overflow chamber. One major advantage to the perimeter sand filter design is that it requires little hydraulic head and thus is a good option in areas of low relief.

Organic Media Filter

Organic media filters are essentially the same as surface filters, with the sand medium replaced with or supplemented by another medium. Two examples are the peat/sand filter (Galli, 1990) and the compost filter system (CSF, 1996). The assumption is that these systems will have enhanced pollutant removal for many compounds because of the increased cation exchange capacity achieved by increasing the organic matter.

Multi-Chamber Treatment Train

The Multi-Chamber Treatment Train (Robertson et al., 1995) is essentially a "deluxe sand filter." This underground system consists of three chambers. Storm water enters into the first chamber, where screening occurs, trapping large sediments and releasing highly volatile materials. The second chamber provides settling of fine sediments and further removal of volatile compounds and also floatable hydrocarbons through the use of fine bubble diffusers and sorbent pads. The final chamber provides filtration by using a sand and peat mixed medium for reduction of the remaining pollutants. The top of the filter is covered by a filter fabric that evenly distributes the water volume and prevents channelization. Although this practice can achieve very high pollutant removal rates, it might be prohibitively expensive in many areas and has been implemented only on an experimental basis.

Exfiltration/Partial Exfiltration

In exfilter designs, all or part of the under drain system is replaced with an open bottom that allows infiltration to the ground water. When the under drain is present, it is used as an overflow device in case the filter becomes clogged. These designs are best applied in the same soils where infiltration practices are used (see Infiltration Basin and Infiltration Trench fact sheets).

Regional Variations

Arid Climates

Filters have not been widely used in arid climates. In these climates, however, it is probably necessary to increase storage in the sediment chamber to account for high sediment loads. Designers should consider increasing the volume of the sediment chamber to up to 40 percent of the water quality volume.

Cold Climates

In cold climates, filters can be used, but surface or perimeter filters will not be effective during the winter months, and unintended consequences might result from a frozen filter bed. Using alternative conveyance measures such as a weir system between the sediment chamber and filter bed may avoid freezing associated with the traditional standpipe. Where possible, the filter bed should be below the frost line. Some filters, such as the peat/sand filter, should be shut down during the winter. These media will become completely impervious during freezing conditions. Using a larger under drain system to encourage rapid draining during the winter months may prevent freezing of the filter bed. Finally, the sediment chamber should be larger in cold climates to account for road sanding (up to 40 percent of the water quality volume).

Limitations

Sand filters can be used in unique conditions where many other storm water management practices are inappropriate, such as in karst (i.e., limestone) topography or in highly urbanized settings. There are several limitations to these practices, however. Sand filters cannot control floods and generally are not designed to protect stream channels from erosion or to recharge the ground water. In addition, sand filters require frequent maintenance, and underground and perimeter versions of these practices are easily forgotten because they are out of sight. Perhaps one of the greatest limitations to sand filters is that they cannot be used to treat large drainage areas. Finally, surface sand filters are generally not aesthetically pleasing management practices. Underground and perimeter sand filters are not visible, and thus do not add or detract from the aesthetic value of a site.

Maintenance Considerations

Intense and frequent maintenance and inspection practices are needed for filter systems. Table 2 outlines some of these requirements.

Table 2: Typical maintenance/inspection activities for filtration systems (Adapted from WMI, 1997; CWP, 1997)

Activity	**Schedule**
• Ensure that contributing area, filtering practice, inlets, and outlets are clear of debris. • Ensure that the contributing area is stabilized and mowed, with clippings removed. • Check to ensure that the filter surface is not clogging (also after moderate and major storms). • Ensure that activities in the drainage area minimize oil/grease and sediment entry to the system. • If a permanent pool is present, ensure that the chamber does not leak and that normal pool level is retained.	Monthly

• Replace sorbent pillows (Multi-Chamber Treatment Train only).	Biannual
• Check to see that the filter bed is clean of sediments, and the sediment chamber is no more than one-half full of sediment. Remove sediment if necessary. • Make sure that there is no evidence of deterioration, sailing, or cracking of concrete. • Inspect grates (if used). • Inspect inlets, outlets, and overflow spillway to ensure good condition and no evidence of erosion. • Repair or replace any damaged structural parts. • Stabilize any eroded areas. • Ensure that flow is not bypassing the facility. • Ensure that no noticeable odors are detected outside the facility.	Annual

Effectiveness
Structural storm water management practices can be used to achieve four broad resource protection goals: flood control, channel protection, ground water recharge, and pollutant removal. Filtering practices are for the most part adapted only to provide pollutant removal.

Ground Water Recharge
In exfilter designs, some ground water recharge can be provided; however, none of the other sand filter designs can provide recharge.

Pollutant Removal
Sand filters are effective storm water management practices for pollutant removal. Removal rates for all sand filters and organic filters are presented in Table 3. With the exception of nitrates, which appear to be exported from filtering systems, they perform relatively well at removing pollutants. The export of nitrates from filters may be caused by mineralization of organic nitrogen in the filter bed. Table 3 shows typical removal efficiencies for sand filters.

Table 3: Sand filter removal efficiencies (percent)

	Sand Filters (Schueler, 1997)	Peat/Sand Filter (Curran, 1996)	Compost Filter System		Multi-Chamber Treatment Train		
			Stewart, 1992	Leif, 1999	Pitt et al., 1997	Pitt, 1996	Greb et al., 1998
TSS	87	66	95	85	85	83	98
TP	51	51	41	4	80	-	84
TN	44	47	-	-	-	-	-
Nitrate	-13	22	-34	-95	-	14	-
Metals	34-80	26-75	61-88	44-75	65-90	91-100	83-89
Bacteria	55	-	-	-	-	-	-

From the few studies available, it is difficult to determine if organic filters necessarily have higher removal efficiencies than sand filters. The Multi-Chamber Treatment Train appears to have high pollutant removal for some constituents, although these data are based on only a handful of studies. The siting and design criteria presented in this fact sheet reflect the best current information and experience to improve the performance of sand filters. A recent joint project of the American Society of Civil Engineers (ASCE) and the U.S. EPA

Office of Water may help to isolate specific design features that can improve performance. The National Stormwater Best Management Practice (BMP) database is a compilation of storm water practices that includes both design information and performance data for various practices. As the database expands, inferences about the extent to which specific design criteria influence pollutant removal may be made. For more information on this database, access the BMP database web page at *http://www.bmpdatabase.org*.

STORM WATER WETLAND

Description

Storm water wetlands (a.k.a. constructed wetlands) are structural practices similar to wet ponds (see Wet Pond fact sheet) that incorporate wetland plants into the design. As storm water runoff flows through the wetland, pollutant removal is achieved through settling and biological uptake within the practice. Wetlands are among the most effective storm water practices in terms of pollutant removal and they also offer aesthetic value. Although natural wetlands can sometimes be used to treat storm water runoff that has been properly pretreated, storm water wetlands are fundamentally different from natural wetland systems. Storm water wetlands are designed specifically for the purpose of treating storm water runoff, and typically have less biodiversity than natural wetlands in terms of both plant and animal life. Several design variations of the storm water wetland exist, each design differing in the relative amounts of shallow and deep water, and dry storage above the wetland.

A distinction should be made between using a constructed wetland for storm water management and diverting storm water into a natural wetland. The latter practice is not recommended because altering the hydrology of the existing wetland with additional storm water can degrade the resource and result in plant die-off and the destruction of wildlife habitat. In all circumstances, natural wetlands should be protected from the adverse effects of development, including impacts from increased storm water runoff. This is especially important because natural wetlands provide storm water and flood control benefits on a regional scale.

Applicability

Constructed wetlands are widely applicable storm water management practices. While they have limited applicability in highly urbanized settings and in arid climates, wetlands have few other restrictions.

Regional Applicability

Storm water wetlands can be applied in most regions of the United States, with the exception of arid climates. In arid and semi-arid climates, it is difficult to design any storm water practice that has a permanent pool. Because storm water wetlands are shallow, a relatively large area is subject to evaporation relative, to the volume of the practice. This makes maintaining the permanent pool in wetlands both more challenging and more important than maintaining the pool of a wet pond (see Wet Pond fact sheet).

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface exists. It is difficult to use wet ponds in the ultra-urban environment because of the land area each wetland consumes. They can, however, be used in an ultra-urban environment if a relatively large area is available downstream of the site.

Storm Water Hot Spots

Storm water hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. A typical example is a gas station. Wetlands can accept runoff from storm water hot spots, but need significant separation from ground water if they will be used for this purpose. Caution also needs to be exercised, if these practices are designed to encourage wildlife use, to ensure that pollutants in storm water runoff do not work their way through the food chain of organisms living in or near the wetland.

Storm Water Retrofit

A storm water retrofit is a storm water management practice (usually structural) put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. When retrofitting an entire watershed, storm water wetlands have the advantage of providing both educational and habitat value. One disadvantage to wetlands, however, is the difficulty of storing large amounts of runoff without consuming a large amount of land. It is also possible to incorporate wetland elements into existing practices, such as wetland plantings (see Wet Pond and Dry Extended Detention Pond fact sheets)

Cold Water (Trout) Streams

Wetlands pose a risk to cold water systems because of their potential for stream warming. When water remains in the permanent pool, it is heated by the sun. A study in Prince George's County, Maryland, investigated the thermal impacts of a wide range of storm water management practices (Galli, 1990). In this study, only one wetland was investigated, which was an extended detention wetland (see Design Variations). The practice increased the average temperature of storm water runoff that flowed through the practice by about 3°F. As a result, it is likely that wetlands increase water temperature.

Siting and Design Considerations

In addition to the broad applicability concerns described above, designers need to consider conditions at the site level. In addition, they need to incorporate design features to improve the longevity and performance of the practice, while minimizing the maintenance burden.

Siting Considerations

In addition to the restrictions and modifications to adapting storm water wetlands to different regions and land uses, designers need to ensure that this management practice is feasible at the site in question. The following section provides basic guidelines for siting wetlands.

Drainage Area

Wetlands need sufficient drainage area to maintain the permanent pool. In humid regions, this is typically about 25 acres, but a greater area may be needed in regions with less rainfall.

Slope

Wetlands can be used on sites with an upstream slope of up to about 15 percent. The local slope should be relatively shallow, however. While there is no minimum slope requirement, there does need to be enough elevation drop from the inlet to the outlet to ensure that hydraulic conveyance by gravity is feasible (generally about 3 to 5 feet).

Soils/Topography

Wetlands can be used in almost all soils and geology, with minor design adjustments for regions of karst (i.e. limestone) topography (see Design Considerations).

Ground Water

Unless they receive hot spot runoff, wetlands can often intersect the ground water table. Some research suggests that pollutant removal is reduced when ground water contributes substantially to the pool volume (Schueler, 1997b). It is assumed that wetlands would have a similar response.

Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. There are some features, however, that should be incorporated into most wetland designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

Pretreatment

Pretreatment incorporates design features that help to settle out coarse sediment particles. By removing these particles from runoff before they reach the large permanent pool, the maintenance burden of the pond is reduced. In wetlands, pretreatment is achieved with a sediment forebay. A sediment forebay is a small pool (typically about 10 percent of the volume of the permanent pool). Coarse particles remain trapped in the forebay, and maintenance is performed on this smaller pool, eliminating the need to dredge the entire pond.

Treatment

Treatment design features help enhance the ability of a storm water management practice to remove pollutants. The purpose of most of these features is to increase the amount of time and flowpath by which storm water remains in the wetland. Some typical design features include

- The surface area of wetlands should be at least 1 percent of the drainage area to the practice.

- Wetlands should have a length-to-width ratio of at least 1.5:1. Making the wetland longer than it is wide helps prevent "short circuiting" of the practice.
- Effective wetland design displays "complex microtopography." In other words, wetlands should have zones of both very shallow (<6 inches) and moderately shallow (<18 inches) wetlands incorporated, using underwater earth berms to create the zones. This design will provide a longer flow path through the wetland to encourage settling, and it provides two depth zones to encourage plant diversity.

Conveyance

Conveyance of storm water runoff into and through a storm water management practice is a critical component of any practice. Storm water should be conveyed to and from practices safely and to minimize erosion potential. The outfall of pond systems should always be stabilized to prevent scour. In addition, an emergency spillway should be provided to safely convey large flood events. To help mitigate warming at the outlet channel, designers should provide shade around the channel at the pond outlet.

Maintenance Reduction

In addition to regular maintenance activities needed to maintain the function of storm water practices, some design features can be incorporated to ease the maintenance burden of each practice. In wetlands, maintenance reduction features include techniques to reduce the amount of maintenance needed, as well as techniques to make regular maintenance activities easier.

One potential maintenance concern in wet ponds is clogging of the outlet. Wetlands should be designed with a nonclogging outlet such as a reverse-slope pipe or a weir outlet with a trash rack. A reverse-slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and establishes the water elevation of the permanent pool. Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris. Another general rule is that no orifice should be less than 3 inches in diameter. Smaller orifices are generally more susceptible to clogging, without specific design considerations to reduce this problem. Another feature that can help reduce the potential for clogging of the outlet is to incorporate a small pool, or "micropool" at the outlet.

Design features are also incorporated to ease maintenance of both the forebay and the main pool of wetlands. Wetlands should be designed with a maintenance access to the forebay to ease this relatively routine (5- to 7-year) maintenance activity. In addition, the permanent pool should have a pond drain to draw down the pond for the more infrequent dredging of the main cell of the wetland.

Landscaping

Landscaping of wetlands can make them an asset to a community and can also enhance the pollutant removal of the practice. In wetland systems, landscaping is an integral part of the design. To ensure the establishment and survival of wetland plants, a landscaping plan should provide detailed information about the plants selected, when they will be planted, and a strategy for maintaining them. The plan should detail wetland plants, as well as vegetation to be established adjacent to the wetland.

A variety of techniques can be used to establish wetland plants. The most effective techniques are the use of nursery stock as dormant rhizomes, live potted plants, and bare rootstock. A "wetland mulch," soil from a natural wetland or a designed "wetland mix," can be used to supplement wetland plantings or alone to establish wetland vegetation. Wetland mulch carries with it the seed bank from the original wetland, and can help to enhance diversity in the wetland. The least expensive option to establish wetlands is to allow the wetland to colonize itself. One disadvantage to this last technique is that invasive species such as cattails or Phragmites may dominate the wetland.

When developing a plan for wetland planting, care needs to be taken to ensure that plants are established in the proper depth and within the planting season. This season varies regionally, and is generally between 2 and 3 months long in the spring to early summer. Plant lists are available for various regions of the United States through wetland nurseries, extension services, and conservation districts.

Design Variations

There are several variations of the wetland design. The designs are characterized by the volume of the wetland in deep pool, high marsh, and low marsh, and whether the design allows for detention of small storms above the wetland surface. Other design variations help to make wetland designs practical in cold climates.

Shallow Marsh

In the shallow marsh design, most of the wetland volume is in the relatively shallow high marsh or low marsh depths. The only deep portions of the shallow wetland design are the forebay at the inlet to the wetland and the micropool at the outlet. One disadvantage to this design is that, since the pool is very shallow, a large amount of land is typically needed to store the water quality volume (i.e., the volume of runoff to be treated in the wetland).

Extended Detention Wetland

This design is the same as the shallow marsh, with additional storage above the surface of the marsh. Storm water is temporarily ponded above the surface in the extended detention zone for between 12 and 24 hours. This design can treat a greater volume of storm water in a smaller space than the shallow wetland design. In the extended detention wetland option, plants that can tolerate wet and dry periods should be specified in the extended detention zone.

Pond/Wetland System

The pond/wetland system combines the wet pond (see Wet Pond fact sheet) design with a shallow marsh. Storm water runoff flows through the wet pond and into the shallow marsh. Like the extended detention wetland, this design requires less surface area than the shallow marsh because some of the volume of the practice is in the relatively deep (i.e., 6–8 feet) pond.

Pocket Wetland

This design is very similar to the pocket pond (see Wet Pond fact sheet). In this design, the bottom of the wetland intersects the ground water, which helps to maintain the permanent pool. Some evidence suggests that ground water flows may reduce the overall effectiveness of storm water management practices (Schueler, 1997b). This option may be used when there is not significant drainage area to maintain a permanent pool.

Gravel-Based Wetlands

In this design, runoff flows through a rock filter with wetland plants at the surface. Pollutants are removed through biological activity on the surface of the rocks, as well as by pollutant uptake of the plants. This practice is fundamentally different from other wetland designs because, while most wetland designs behave like wet ponds with differences in grading and landscaping, gravel-based wetlands are more similar to a filtering system.

Regional Variations

Cold Climates

Cold climates present many challenges to designers of wetlands. During the spring snowmelt, a large volume of water runs off in a short time, carrying a relatively high pollutant load. In addition, cold winter temperatures may cause freezing of the permanent pool or freezing at inlets and outlets. Finally, high salt concentrations in runoff resulting from road salting, as well as sediment loads from road sanding, may impact wetland vegetation.

One of the greatest challenges of storm water wetlands, particularly shallow marshes, is that much of the practice is very shallow. Therefore, much of the volume in the wetland can be lost as the surface of the practice freezes. One study found that the performance of a wetland system was diminished during the spring snowmelt because the outlet and surface of the wetland had frozen. Sediment and pollutants in snowmelt and rainfall events "skated" over the surface of the wetland, depositing at the outlet of the wetland. When the ice melted, this sediment was washed away by storm events (Oberts, 1994). Several design features can help minimize this problem, including:

- "On-line" designs allowing flow to move continuously can help prevent outlets from freezing.
- Wetlands should be designed with multiple cells, with a berm or weir separating each cell. This modification will help to retain storage for treatment above the ice layer during the winter season.
- Outlets that are resistant to freezing should be used. Some examples include weirs or pipes with large diameters.

The salt and sand used to remove ice from roads and parking lots may also create a challenge to designing wetlands in cold climates. When wetlands drain highway runoff, or parking lots, salt-tolerant vegetation, such as pickle weed or cord grass should be used. (Contact a local nursery or extension agency for more information in your region). In addition, designers should consider using a large forebay to capture the sediment from road sanding.

Karst Topography

In karst (i.e., limestone) topography, wetlands should be designed with an impermeable liner to prevent ground water contamination or sinkhole formation, and to help maintain the permanent pool.

Limitations

Some features of storm water wetlands that may make the design challenging include the following:

- Each wetland consumes a relatively large amount of space, making it an impractical option on many sites.
- Improperly designed wetlands can become a breeding area for mosquitoes.
- Wetlands require careful design and planning to ensure that wetland plants are sustained after the practice is in place.
- It is possible that storm water wetlands may release nutrients during the nongrowing season.
- Designers need to ensure that wetlands do not negatively impact natural wetlands or forest during the design phase.
- Wetlands consume a large amount of land. This characteristic may limit their use in areas where land values are high.

Maintenance Considerations

In addition to incorporating features into the wetland design to minimize maintenance, some regular maintenance and inspection practices are needed. Table 1 outlines these practices.

Table 1. Regular maintenance activities for wetlands (Source: Adapted from WMI, 1997, and CWP, 1998)

Activity	**Schedule**
• Replace 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
• Supplement wetland plants if a significant portion have not established (at least 50% of the surface area). • Harvest wetland plants that have been "choked out" by sediment build-up.	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

Effectiveness

Structural storm water management practices can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. Wetlands can provide flood control, channel protection, and pollutant removal.

Flood Control

One objective of storm water management practices can be to reduce the flood hazard associated with large storm events by reducing the peak flow associated with these storms. Wetlands can easily be designed for flood control by providing flood storage above the level of the permanent pool.

Channel Protection

When used for channel protection, wetlands have traditionally controlled the 2-year storm. It appears that this control has been relatively ineffective, and recent research suggests that control of a smaller storm may be more appropriate (MacRae, 1996).

Ground Water Recharge

Wetlands cannot provide ground water recharge. The build-up of debris at the bottom of the wetland prevents the movement of water into the subsoil.

Pollutant Removal

Wetlands are among the most effective storm water management practices at removing storm water pollutants. A wide range of research is available to estimate the effectiveness of wetlands. Wetlands have high pollutant removal rates, and are more effective than any other practice at removing nitrate and bacteria. Table 2 provides pollutant removal data derived from the Center for Watershed Protections's National Pollutant Removal Database for Stormwater Treatment Practices (Winer, 2000).

Table 2. Typical Pollutant Removal Rates of Wetlands (%) (Winer, 2000)

Pollutant	**Stormwater Treatment Practice Design Variation**			
	Shallow Marsh	ED Wetland[1]	Pond/Wetland System	Submerged Gravel Wetland[1]
TSS	83±51	69	71±35	83
TP	43±40	39	56±35	64
TN	26±49	56	19±29	19
NOx	73±49	35	40±68	81
Metals	36–85	(-80)–63	0–57	21–83
Bacteria	76[1]	NA	NA	78

[1]Data based on fewer than five data points

The effectiveness of wetlands varies considerably, but many believe that proper design and maintenance might help to improve their performance. The siting and design criteria presented in this sheet reflect the best current information and experience to improve the performance of wetlands. A recent joint project of the American Society of Civil Engineers (ASCE) and the U.S. EPA Office of Water may help to isolate specific design features that can improve performance. The National Stormwater Best Management Practice (BMP) database is a compilation of storm water practices which includes both design information and performance data for various practices. As the database expands, inferences about the extent to which specific design criteria influence pollutant removal may be made. More information on this database is available on the BMP database web page at http://www.bmpdatabase.org.

GRASSED SWALES

Description

The term swale (a.k.a. grassed channel, dry swale, wet swale, biofilter) refers to a series of vegetated, open channel management practices designed specifically to treat and attenuate storm water runoff for a specified water quality volume. As storm water runoff flows through these channels, it is treated through filtering by the vegetation in the channel, filtering through a subsoil matrix, and/or infiltration into the underlying soils. Variations of the grassed swale include the grassed channel, dry swale, and wet swale. The specific design features and methods of treatment differ in each of these designs, but all are improvements on the traditional drainage ditch. These designs incorporate modified geometry and other features for use of the swale as a treatment and conveyance practice.

Applicability

Grassed swales can be applied in most situations with some restrictions. Swales are very well suited for treating highway or residential road runoff because they are linear practices.

Regional Applicability

Grassed swales can be applied in most regions of the country. In arid and semi-arid climates, however, the value of these practices needs to be weighed against the water needed to irrigate them.

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface exists. Grassed swales are generally not well suited to ultra-urban areas because they require a relatively large area of pervious surfaces.

Storm Water Hot Spots

Storm water hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. A typical example is a gas station or convenience store. With the exception of the dry swale design (see Design Variations), hot spot runoff should not be directed toward grassed channels. These practices either infiltrate storm water or intersect the ground water, making use of the practices for hot spot runoff a threat to ground water quality.

Storm Water Retrofit

A storm water retrofit is a storm water management practice (usually structural) put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. One retrofit opportunity using grassed swales modifies existing drainage ditches. Ditches have traditionally been designed only to convey storm water away from roads. In some cases, it may be possible to incorporate features to enhance pollutant removal or infiltration such as check dams (i.e., small dams along the ditch that trap sediment, slow runoff, and reduce the longitudinal slope). Since grassed swales cannot treat a large area, using this practice to retrofit an entire watershed would be expensive because of the number of practices needed to manage runoff from a significant amount of the watershed's land area.

Cold Water (Trout) Streams

Grassed channels are a good treatment option within watersheds that drain to cold water streams. These practices do not pond water for a long period of time and often induce infiltration. As a result, standing water will not typically be subjected to warming by the sun in these practices.

Siting and Design Considerations

In addition to the broad applicability concerns described above, designers need to consider conditions at the site level. In addition, they need to incorporate design features to improve the longevity and performance of the practice, while minimizing the maintenance burden.

Siting Considerations

In addition to considering the restrictions and adaptations of grassed swales to different regions and land uses, designers need to ensure that this management practice is feasible at the site in question because some site conditions (i.e., steep slopes, highly impermeable soils) might restrict the effectiveness of grassed channels.

Drainage Area
Grassed swales should generally treat small drainage areas of less than 5 acres. If the practices are used to treat larger areas, the flows and volumes through the swale become too large to design the practice to treat storm water runoff through infiltration and filtering.
Slope
Grassed swales should be used on sites with relatively flat slopes of less than 4 percent slope; 1 to 2 percent slope is recommended. Runoff velocities within the channel become too high on steeper slopes. This can cause erosion and does not allow for infiltration or filtering in the swale.
Soils / Topography
Grassed swales can be used on most soils, with some restrictions on the most impermeable soils. In the dry swale (see Design Variations) a fabricated soil bed replaces on-site soils in order to ensure that runoff is filtered as it travels through the soils of the swale.
Ground Water
The depth to ground water depends on the type of swale used. In the dry swale and grassed channel options, designers should separate the bottom of the swale from the ground water by at least 2 ft to prevent a moist swale bottom, or contamination of the ground water. In the wet swale option, treatment is enhanced by a wet pool in the practice, which is maintained by intersecting the ground water.
Design Considerations
Although there are different design variations of the grassed swale (see Design Variations), there are some design considerations common to all three. One overriding similarity is the cross-sectional geometry of all three options. Swales should generally have a trapezoidal or parabolic cross section with relatively flat side slopes (flatter than 3:1). Designing the channel with flat side slopes maximizes the wetted perimeter. The wetted perimeter is the length along the edge of the swale cross section where runoff flowing through the swale is in contact with the vegetated sides and bottom of the swale. Increasing the wetted perimeter slows runoff velocities and provides more contact with vegetation to encourage filtering and infiltration. Another advantage to flat side slopes is that runoff entering the grassed swale from the side receives some pretreatment along the side slope. The flat bottom of all three should be between 2–8 ft wide. The minimum width ensures a minimum filtering surface for water quality treatment, and the maximum width prevents braiding, the formation of small channels within the swale bottom.
Another similarity among all three designs is the type of pretreatment needed. In all three design options, a small forebay should be used at the front of the swale to trap incoming sediments. A pea gravel diaphragm, a small trench filled with river run gravel, should be used as pretreatment for runoff entering the sides of the swale.
Two other features designed to enhance the treatment ability of grassed swales are a flat longitudinal slope (generally between 1 percent and 2 percent) and a dense vegetative cover in the channel. The flat slope helps to reduce the velocity of flow in the channel. The dense vegetation also helps reduce velocities, protect the channel from erosion, and act as a filter to treat storm water runoff. During construction, it is important to stabilize the channel before the turf has been established, either with a temporary grass cover or with the use of natural or synthetic erosion control products.
In addition to treating runoff for water quality, grassed swales need to convey larger storms safely. Typical designs allow the runoff from the 2-year storm (i.e., the storm that occurs, on average, once every two years) to flow through the swale without causing erosion. Swales should also have the capacity to pass larger storms (typically a 10-year storm) safely.
Design Variations
The following discussion identifies three different variations of open channel practices, including the grassed channel, the dry swale, and the wet swale.
Grassed Channel
Of the three grassed swale designs, grassed channels are the most similar to a conventional drainage ditch, with the major differences being flatter side slopes and longitudinal slopes, and a slower design velocity for water quality treatment of small storm events. Of all of the grassed swale options, grassed channels are the

least expensive but also provide the least reliable pollutant removal. The best application of a grassed channel is as pretreatment to other structural storm water practices.

One major difference between the grassed channel and most of the other structural practices is the method used to size the practice. Most storm water management water quality practices are sized by volume. This method sets the volume available in the practice equal to the water quality volume, or the volume of water to be treated in the practice. The grassed channel, on the other hand, is a flow-rate-based design. Based on the peak flow from the water quality storm (this varies from region to region, but a typical value is the 1-inch storm), the channel should be designed so that runoff takes, on average, 10 minutes to flow from the top to the bottom of the channel. A procedure for this design can be found in *Design of Storm Water Filtering Systems* (CWP, 1996).

Dry Swales

Dry swales are similar in design to bioretention areas (see Bioretention fact sheet). These designs incorporate a fabricated soil bed into their design. The existing soil is replaced with a sand/soil mix that meets minimum permeability requirements. An underdrain system is used under the soil bed. This system is a gravel layer that encases a perforated pipe. Storm water treated in the soil bed flows through the bottom into the underdrain, which conveys this treated storm water to the storm drain system. Dry swales are a relatively new design, but studies of swales with a native soil similar to the man-made soil bed of dry swales suggest high pollutant removal.

Wet Swales

Wet swales intersect the ground water and behave almost like a linear wetland cell (see Storm Water Wetland fact sheet). This design variation incorporates a shallow permanent pool and wetland vegetation to provide storm water treatment. This design also has potentially high pollutant removal. One disadvantage to the wet swale is that it cannot be used in residential or commercial settings because the shallow standing water in the swale is often viewed as a potential nuisance by homeowners and also breeds mosquitos.

Regional Variations

Cold Climates

In cold or snowy climates, swales may serve a dual purpose by acting as both a snow storage/treatment and a storm water management practice. This dual purpose is particularly relevant when swales are used to treat road runoff. If used for this purpose, swales should incorporate salt-tolerant vegetation, such as creeping bentgrass.

Arid Climates

In arid or semi-arid climates, swales should be designed with drought-tolerant vegetation, such as buffalo grass. As pointed out in the Applicability section, the value of vegetated practices for water quality needs to be weighed against the cost of water needed to maintain them in arid and semi-arid regions.

Limitations

Grassed swales have some limitations, including the following:

- Grassed swales cannot treat a very large drainage area.
- Wet swales may become a nuisance due to mosquito breeding.
- If designed improperly (e.g., if proper slope is not achieved), grassed channels will have very little pollutant removal.
- A thick vegetative cover is needed for these practices to function properly.

Maintenance Considerations

Maintenance of grassed swales mostly involves maintenance of the grass or wetland plant cover. Typical maintenance activities are included in Table 1.

Table 1. Typical maintenance activities for grassed swales (Source: Adapted from CWP, 1996)

Activity	**Schedule**
• Inspect pea gravel diaphragm for clogging and correct the problem. • Inspect grass along side slopes for erosion and formation of rills or gullies and correct.	Annual (semi-annual the first year)

• Remove trash and debris accumulated in the inflow forebay. • Inspect and correct erosion problems in the sand/soil bed of dry swales. • Based on inspection, plant an alternative grass species if the original grass cover has not been successfully established. • Replant wetland species (for wet swale) if not sufficiently established.	
• Rototill or cultivate the surface of the sand/soil bed of dry swales if the swale does not draw down within 48 hours. • Remove sediment build-up within the bottom of the swale once it has accumulated to 25 percent of the original design volume.	As needed (infrequent)
• Mow grass to maintain a height of 3–4 inches	As needed (frequent seasonally)

Effectiveness
Structural storm water management practices can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. Grassed swales can be used to meet ground water recharge and pollutant removal goals.

Ground Water Recharge
Grassed channels and dry swales can provide some ground water recharge as infiltration is achieved within the practice. Wet swales, however, generally do not contribute to ground water recharge. Infiltration is impeded by the accumulation of debris on the bottom of the swale.

Pollutant Removal
Few studies are available regarding the effectiveness of grassed channels. In fact, only 9 studies have been conducted on all grassed channels designed for water quality (Table 2). The data suggest relatively high removal rates for some pollutants, but negative removals for some bacteria, and fair performance for phosphorous. One study of available performance data (Schueler, 1997) estimates the removal rates for grassed channels as:
Total Suspended Solids: 81%
Total Phosphorous: 29%
Nitrate Nitrogen: 38%
Metals: 14% to 55%
Bacteria: -50%

Table 2. Grassed swale pollutant removal efficiency data

Removal Efficiencies (% Removal)							
Study	**TSS**	**TP**	**TN**	**NO_3**	**Metals**	**Bacteria**	**Type**
Goldberg 1993	67.8	4.5	-	31.4	42–62	-100	grassed channel
Seattle Metro and Washington Department of Ecology 1992	60	45	-	-25	2–16	-25	grassed channel
Seattle Metro and Washington Department of	83	29	-	-25	46–73	-25	grassed channel

Ecology, 1992							
Wang et al., 1981	80	-	-	-	70–80	-	dry swale
Dorman et al., 1989	98	18	-	45	37–81	-	dry swale
Harper, 1988	87	83	84	80	88–90	-	dry swale
Kercher et al., 1983	99	99	99	99	99	-	dry swale
Harper, 1988.	81	17	40	52	37–69	-	wet swale
Koon, 1995	67	39	-	9	-35 to 6	-	wet swale
Occoquan Watershed Monitoring Lab, 1983	-100	-100	-100	-	-100	-	drainage channel
Yousef et al., 1985	-	8	13	11	14–29	-	drainage channel
Occoquan Watershed Monitoring Lab, 1983	-50	-9.1	-18.2	-	-100	-	drainage channel
Yousef et al., 1985	-	-19.5	8	2	41–90	-	drainage channel
Occoquan Watershed Monitoring Lab, 1983	31	-23	36.5	-	-100 to 33	-	drainage channel
Welborn and Veenhuis, 1987	0	-25	-25	-25	0	-	drainage channel
Yu et al., 1993	68	60	-	-	74	-	drainage channel
Dorman et al., 1989	65	41	-	11	14-55	-	drainage channel
Pitt and McLean, 1986	0	-	0	-	0	0	drainage channel
Oakland, 1983	33	-25	-	-	20–58	0	drainage channel
Dorman et al., 1989	-85	12	-	-100	14–88	-	drainage channel

While it is difficult to distinguish between different designs based on the small amount of available data, grassed channels generally have poorer removal rates than wet and dry swales, although wet swales appear to export soluble phosphorous (Harper, 1988; Koon, 1995). It is not clear why swales export bacteria. One explanation is that bacteria thrive in the warm swale soils. Another is that studies have not accounted for some sources of bacteria, such as local residents walking dogs within the grassed swale area.

GRASSED FILTER STRIP

Description

Grassed filter strips (vegetated filter strips, filter strips, and grassed filters) are vegetated surfaces that are designed to treat sheet flow from adjacent surfaces. Filter strips function by slowing runoff velocities and filtering out sediment and other pollutants, and by providing some infiltration into underlying soils. Filter strips were originally used as an agricultural treatment practice, and have more recently evolved into an urban practice. With proper design and maintenance, filter strips can provide relatively high pollutant removal. One challenge associated with filter strips, however, is that it is difficult to maintain sheet flow, so the practice may be "short circuited" by concentrated flows, receiving little or no treatment.

Applicability

Filter strips are applicable in most regions, but are restricted in some situations because they consume a large amount of space relative to other practices. Filter strips are best suited to treating runoff from roads and highways, roof downspouts, very small parking lots, and pervious surfaces. They are also ideal components of the "outer zone" of a stream buffer (see Buffer Zones fact sheet), or as pretreatment to a structural practice. This recommendation is consistent with recommendations in the agricultural setting that filter strips are most effective when combined with another practice (Magette et al., 1989). In fact, the most recent storm water manual for Maryland does not consider the filter strip as a treatment practice, but does offer storm water volume reductions in exchange for using filter strips to treat some of a site.

Regional Applicability

Filter strips can be applied in most regions of the country. In arid areas, however, the cost of irrigating the grass on the practice will most likely outweigh its water quality benefits.

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface exists. Filter strips are impractical in ultra-urban areas because they consume a large amount of space.

Storm Water Hot Spots

Storm water hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. A typical example is a gas station. Filter strips should not receive hot spot runoff, because the practice encourages infiltration. In addition, it is questionable whether this practice can reliably remove pollutants, so it should definitely not be used as the sole treatment of hot spot runoff.

Storm Water Retrofit

A storm water retrofit is a storm water management practice (usually structural), put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Filter strips are generally a poor retrofit option because they consume a relatively large amount of space and cannot treat large drainage areas.

Cold Water (Trout) Streams

Some cold water species, such as trout, are sensitive to changes in temperature. While some treatment practices, such as wet ponds (see Wet Ponds fact sheet), can warm storm water substantially, filter strips do not warm pond water on the surface for long periods of time and are not expected to increase storm water temperatures. Thus, these practices are good for protection of cold-water streams.

Siting and Design Considerations

Siting Considerations

In addition to the restrictions and modifications to adapting filter strips to different regions and land uses, designers need to ensure that this management practice is feasible at the site in question. The following section provides basic guidelines for siting filter strips.

Drainage Area

Typically, filter strips are used to treat very small drainage areas. The limiting design factor, however, is not the drainage area the practice treats but the length of flow leading to it. As storm water runoff flows over the ground's surface, it changes from sheet flow to concentrated flow. Rather than moving uniformly over the surface, the concentrated flow forms rivulets which are slightly deeper and cover less area than the sheet flow. When flow concentrates, it moves too rapidly to be effectively treated by a grassed filter strip. As a rule, flow concentrates within a maximum of 75 feet for impervious surfaces, and 150 feet for pervious surfaces (CWP, 1996). Using this rule, a filter strip can treat one acre of impervious surface per 580-foot length.

Slope
Filter strips should be designed on slopes between 2 and 6 percent. Greater slopes than this would encourage the formation of concentrated flow. Except in the case of very sandy or gravelly soil, runoff would pond on the surface on slopes flatter than 2 percent, creating potential mosquito breeding habitat.
Soils /Topography
Filter strips should not be used on soils with a high clay content, because they require some infiltration for proper treatment. Very poor soils that cannot sustain a grass cover crop are also a limiting factor.
Ground Water
Filter strips should be separated from the ground water by between 2 and 4 ft to prevent contamination and to ensure that the filter strip does not remain wet between storms.
Design Considerations
Filter strips appear to be a minimal design practice because they are basically no more than a grassed slope. However, some design features are critical to ensure that the filter strip provides some minimum amount of water quality treatment.

- A pea gravel diaphragm should be used at the top of the slope. The pea gravel diaphragm (a small trench running along the top of the filter strip) serves two purposes. First, it acts as a pretreatment device, settling out sediment particles before they reach the practice. Second, it acts as a level spreader, maintaining sheet flow as runoff flows over the filter strip.
- The filter strip should be designed with a pervious berm of sand and gravel at the toe of the slope. This feature provides an area for shallow ponding at the bottom of the filter strip. Runoff ponds behind the berm and gradually flows through outlet pipes in the berm. The volume ponded behind the berm should be equal to the water quality volume. The water quality volume is the amount of runoff that will be treated for pollutant removal in the practice. Typical water quality volumes are the runoff from a 1-inch storm or ½-inch of runoff over the entire drainage area to the practice.
- The filter strip should be at least 25 feet long to provide water quality treatment.
- Designers should choose a grass that can withstand relatively high velocity flows and both wet and dry periods.
- Both the top and toe of the slope should be as flat as possible to encourage sheet flow and prevent erosion.

Regional Variations
In cold climates, filter strips provide a convenient area for snow storage and treatment. If used for this purpose, vegetation in the filter strip should be salt-tolerant, (e.g., creeping bentgrass), and a maintenance schedule should include the removal of sand built up at the bottom of the slope. In arid or semi-arid climates, designers should specify drought-tolerant grasses (e.g., buffalo grass) to minimize irrigation requirements.

Limitations

Filter strips have several limitations related to their performance and space consumption:

- The practice has not been shown to achieve high pollutant removal.
- Filter strips require a large amount of space, typically equal to the impervious area they treat, making them often infeasible in urban environments where land prices are high.
- If improperly designed, filter strips can become a mosquito breeding ground.
- Proper design requires a great deal of finesse, and slight problems in the design, such as improper grading, can render the practice ineffective in terms of pollutant removal.

Maintenance Considerations

Filter strips require similar maintenance to other vegetative practices (see Grassed Swales fact sheet). These maintenance needs are outlined below. Maintenance is very important for filter strips, particularly in terms of ensuring that flow does not short circuit the practice.

Table 1. Typical maintenance activities for grassed filter strips (Source: CWP, 1996)

Activity	**Schedule**
• Inspect pea gravel diaphragm for clogging and remove built-up sediment.	Annual inspection (semi-annual the first

• Inspect vegetation for rills and gullies and correct. Seed or sod bare areas. • Inspect to ensure that grass has established. If not, replace with an alternative species.	year)
• Mow grass to maintain a 3–4 inch height	Regular (frequent)
• Remove sediment build-up within the bottom when it has accumulated to 25% of the original capacity.	Regular (infrequent)

Effectiveness
Structural storm water management practices can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. The first two goals, flood control and channel protection, require that a storm water practice be able to reduce the peak flows of relatively large storm events (at least 1- to 2-year storms for channel protection and at least 10- to 50-year storms for flood control). Filter strips do not have the capacity to detain these events, but can be designed with a bypass system that routes these flows around the practice entirely.
Filter strips can provide a small amount of ground water recharge as runoff flows over the vegetated surface and ponds at the toe of the slope. In addition, it is believed that filter strips can provide modest pollutant removal. Studies from agricultural settings suggest that a 15-foot-wide grass buffer can achieve a 50 percent removal rate of nitrogen, phosphorus, and sediment, and that a 100-foot buffer can reach closer to 70 percent removal of these constituents (Desbonette et al., 1994). It is unclear how these results can be translated to the urban environment, however. The characteristics of the incoming flows are radically different both in terms of pollutant concentration and the peak flows associated with similar storm events. To date, only one study (Yu et al., 1992) has investigated the effectiveness of a grassed filter strip to treat runoff from a large parking lot. The study found that the pollutant removal varied depending on the length of flow in the filter strip. The narrower (75-foot) filter strip had moderate removal for some pollutants and actually appeared to export lead, phosphorus, and nutrients (See Table 2).

Table 2. Pollutant removal of an urban vegetated filter strip (Source: Yu et al., 1993)

	Pollutant Removal (%)	
	75-Ft Filter Strip	150-Ft Filter Strip
Total suspended solids	54	84
Nitrate+nitrite	-27	20
Total phosphorus	-25	40
Extractable lead	-16	50
Extractable zinc	47	55

CATCH BASINS/CATCH BASIN INSERT
Description
A catch basin (a.k.a. storm drain inlet, curb inlet) is an inlet to the storm drain system that typically includes a grate or curb inlet and a sump to capture sediment, debris, and associated pollutants. They are also used in combined sewer overflow (CSO) watersheds to capture floatables and settle some solids. Catch basins act as pretreatment for other treatment practices by capturing large sediments. The performance of catch basins at removing sediment and other pollutants depends on the design of the catch basin (e.g., the size of the sump) and maintenance procedures to retain the storage available in the sump to capture sediment.

Catch basin efficiency can be improved using inserts, which can be designed to remove oil and grease, trash, debris, and sediment. Some inserts are designed to drop directly into existing catch basins, while others may require extensive retrofit construction.

Applicability

Catch basins are used in drainage systems throughout the United States. However, many catch basins are not ideally designed for sediment and pollutant capture. Ideal application of catch basins is as pretreatment to another storm water management practice. Retrofitting existing catch basins may help to improve their performance substantially. A simple retrofit option is to ensure that all catch basins have a hooded outlet to prevent floatable materials, such as trash and debris, from entering the storm drain system. Catch basin inserts for both new development and retrofits at existing sites may be preferred when available land is limited, as in urbanized areas.

Limitations

Catch basins have three major limitations, including:

- Even ideally designed catch basins cannot remove pollutants as well as structural storm water management practices, such as wet ponds, sand filters, and storm water wetlands.
- Unless frequently maintained, catch basins can become a source of pollutants through resuspension.
- Catch basins cannot effectively remove soluble pollutants or fine particles.

Siting and Design Considerations

The performance of catch basins is related to the volume in the sump (i.e., the storage in the catch basin below the outlet). Lager et al. (1997) described an "optimal" catch basin sizing criterion, which relates all catch basin dimensions to the diameter of the outlet pipe (D):

- The diameter of the catch basin should be equal to 4D.
- The sump depth should be at least 4D. This depth should be increased if cleaning is infrequent or if the area draining to the catch basin has high sediment loads.
- The top of the outlet pipe should be 1.5 D from the bottom of the inlet to the catch basin.

Catch basins can also be sized to accommodate the volume of sediment that enters the system. Pitt et al. (1997) propose a sizing criterion based on the concentration of sediment in storm water runoff. The catch basin is sized, with a factor of safety, to accommodate the annual sediment load in the catch basin sump. This method is preferable where high sediment loads are anticipated, and where the optimal design described above is suspected to provide little treatment.

The basic design should also incorporate a hooded outlet to prevent floatable materials and trash from entering the storm drain system. Adding a screen to the top of the catch basin would not likely improve the performance of catch basins for pollutant removal, but would help capture trash entering the catch basin (Pitt et al., 1997).

Several varieties of catch basin inserts exist for filtering runoff. There are two basic catch basin insert varieties. One insert option consists of a series of trays, with the top tray serving as an initial sediment trap, and the underlying trays composed of media filters. Another option uses filter fabric to remove pollutants from storm water runoff. Yet another option is a plastic box that fits directly into the catch basin. The box construction is the filtering medium. Hydrocarbons are removed as the storm water passes through the box while trash, rubbish, and sediment remain in the box itself as storm water exits. These devices have a very small volume, compared to the volume of the catch basin sump, and would typically require very frequent sediment removal. Bench test studies found that a variety of options showed little removal of total suspended solids, partially due to scouring from relatively small (6-month) storm events (ICBIC, 1995).

One design adaptation of the standard catch basin is to incorporate infiltration through the catch basin bottom. Two challenges are associated with this design. The first is potential ground water impacts, and the second is potential clogging, preventing infiltration. Infiltrating catch basins should not be used in commercial or industrial areas, because of possible ground water contamination. While it is difficult to prevent clogging at the bottom of the catch basin, it might be possible to incorporate some pretreatment into the design.

Maintenance Considerations
Typical maintenance of catch basins includes trash removal if a screen or other debris capturing device is used, and removal of sediment using a vactor truck. Operators need to be properly trained in catch basin maintenance. Maintenance should include keeping a log of the amount of sediment collected and the date of removal. Some cities have incorporated the use of GIS systems to track sediment collection and to optimize future catch basin cleaning efforts.
One study (Pitt, 1985) concluded that catch basins can capture sediments up to approximately 60 percent of the sump volume. When sediment fills greater than 60 percent of their volume, catch basins reach steady state. Storm flows can then resuspend sediments trapped in the catch basin, and will bypass treatment. Frequent clean-out can retain the volume in the catch basin sump available for treatment of storm water flows.
At a minimum, catch basins should be cleaned once or twice per year (Aronson et al., 1993). Two studies suggest that increasing the frequency of maintenance can improve the performance of catch basins, particularly in industrial or commercial areas. One study of 60 catch basins in Alameda County, California, found that increasing the maintenance frequency from once per year to twice per year could increase the total sediment removed by catch basins on an annual basis (Mineart and Singh, 1994). Annual sediment removed per inlet was 54 pounds for annual cleaning, 70 pounds for semi-annual and quarterly cleaning, and 160 pounds for monthly cleaning. For catch basins draining industrial uses, monthly cleaning increased total annual sediment collected to six times the amount collected by annual cleaning (180 pounds versus 30 pounds). These results suggest that, at least for industrial uses, more frequent cleaning of catch basins may improve efficiency. However, the cost of increased operation and maintenance costs needs to be weighed against the improved pollutant removal.
In some regions, it may be difficult to find environmentally acceptable disposal methods for collected sediments. The sediments may not always be land-filled, land-applied, or introduced into the sanitary sewer system due to hazardous waste, pretreatment, or ground water regulations. This is particularly true when catch basins drain runoff from hot spot areas.
Effectiveness
What is known about the effectiveness of catch basins is limited to a few studies. Table 1 outlines the results of some of these studies.

Table 1. Pollutant removal of catch basins (percent).

Study	**Notes**	**TSS[a]**	**COD[a]**	**BOD[a]**	**TN[a]**	**TP[a]**	**Metals**
Pitt et al., 1997	–	32	–		–	–	–
Aronson et al., 1983	Only very small storms were monitored in this study.	60–97	10–56	54–88	–	–	–
Mineart and Singh, 1994	Annual load reduction estimated based on concentrations and mass of catch basin sediment.	–	–	–	–	–	For Copper: 3–4% (Annual cleaning) 15% (Monthly cleaning)

[a] TSS=total suspended solids; COD=chemical oxygen demand; BOD=biological oxygen demand; TN=total nitrogen; TP=total phosphorus

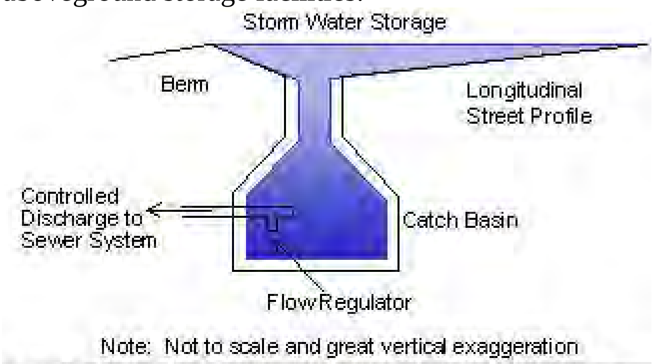
IN-LINE STORAGE

Description

In-line storage refers to a number of practices designed to use the storage within the storm drain system to detain flows. While these practices can reduce storm peak flows, they are unable to improve water quality or protect downstream channels. Storage is achieved by placing devices in the storm drain system to restrict the rate of flow. Devices can slow the rate of flow by backing up flow, as in the case of a dam or weir, or through the use of vortex valves, devices that reduce flow rates by creating a helical flow path in the structure. A description of various flow regulators is included in Urbonas and Stahre (1990).

Applicability

In-line storage practices serve the same purpose as traditional detention basins (see Dry Extended Detention Pond). These practices can act as a surrogate for aboveground storage when little space is available for aboveground storage facilities.



Catch basins can be equipped with flow restrictors to temporarily detain storm water in the conveyance system

Limitations

In-line storage has several limitations, including:

- In-line storage practices only control flow, and thus are not able to improve the water quality of storm water runoff.
- If improperly designed, these practices may cause upstream flooding.

Siting and Design Considerations

Flow regulators cannot be applied to all storm drain systems. In older cities, the storm drainpipes may not be oversized, and detaining storm water within them would cause upstream flooding. Another important issue in siting these practices is the slope of the pipes in the system. In areas with very flat slopes, restricting flow within the system is likely to cause upstream flooding because introducing a regulator into the system will cause flows to back up a long distance before the regulator. In steep pipes, on the other hand, a storage flow regulator cannot utilize much of the storage available in the storm drain system.

Maintenance Considerations

Flow regulators require very little maintenance, because they are designed to be "self cleaning," much like the storm drain system. In some cases, flow regulators may be modified based on downstream flows, new connections to the storm drain, or the application of other flow regulators within the system. For some designs, such as check dams, regulations will require only moderate construction in order to modify the structure's design.

Effectiveness

The effectiveness of in-line storage practices is site-specific and depends on the storage available in the storm drain system. In one study, a single application was able to reduce peak flows by approximately 50 percent (VDCR, 1999).

MANUFACTURED PRODUCTS FOR STORM WATER INLETS

Description

A variety of products for storm water inlets known as swirl separators, or hydrodynamic structures, have been widely applied in recent years. Swirl separators are modifications of the traditional oil-grit separator and include an internal component that creates a swirling motion as storm water flows through a cylindrical chamber. The concept behind these designs is that sediments settle out as storm water moves in this swirling path. Additional compartments or chambers are sometimes present to trap oil and other floatables. There are several different types of proprietary separators, each of which incorporates slightly different design variations, such as off-line application. Another common manufactured product is the catch basin insert. These products are discussed briefly in the Catch Basin fact sheet.

Applicability

Swirl separators are best installed on highly impervious sites. Because little data are available on their performance, and independently conducted studies suggest marginal pollutant removal, swirl separators should not be used as a stand-alone practice for new development. The best application of these products is as pretreatment to another storm water device, or in a retrofit situation where space is limited.

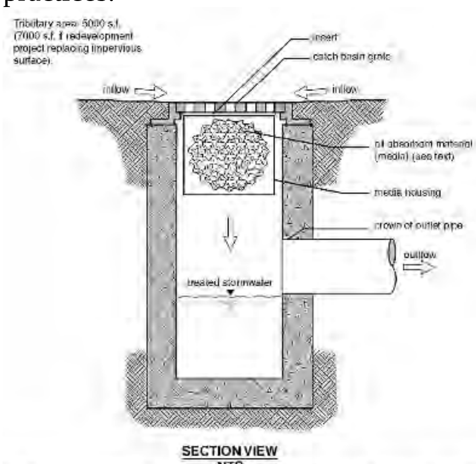
Limitations

Limitations to swirl separators include:

- Very little data are available on the performance of these practices, and independent studies suggest only moderate pollutant removal. In particular, these practices are ineffective at removing fine particles and soluble pollutants.
    - The practice has a high maintenance burden (i.e., frequent cleanout).
    - Swirl concentrators are restricted to small and highly impervious sites.

Siting and Design Considerations

The specific design of swirl concentrators is specified by product literature available from each manufacturer. For the most part, swirl concentrators are a rate-based design. That is, they are sized based on the peak flow of a specific storm event. This design contrasts with most other storm water management practices, which are sized based on capturing and storing or treating a specific volume. Sizing based on flow rate allows the practice to provide treatment within a much smaller area than other storm water management practices.



The typical design of a catch basin insert is a set of filters that are specifically chosen to address the pollutants expected at that site (Source: King County, Washington, 2000)

Maintenance Considerations

Swirl concentrators require frequent maintenance (typically quarterly). Maintenance is performed using a vactor truck, as is used for catch basins (see Catch Basin). In some regions, it may be difficult to find environmentally acceptable disposal methods. The sediments may not always be land-filled, land-applied, or introduced into the sanitary sewer system due to hazardous waste, pretreatment, or groundwater regulations. This is particularly true when catch basins drain runoff from hot spot areas.

Effectiveness
While manufacturers' literature typically reports removal rates for swirl separator design, there is actually very little independent data to evaluate the effectiveness of these products. Two studies investigated one of these products. Both studies reported moderate pollutant removal. While the product outperforms oil/grit separators, which have virtually no pollutant removal (Schueler, 1997), the removal rates are not substantially different from the standard catch basin. One long-term advantage of these products over catch basins is that, if they incorporate an off-line design, trapped sediment will not become resuspended. Data from two studies are presented below. Both of these studies are summarized in a Claytor (1999).

Table 1. Effectiveness of manufactured products for storm water inlets

Study	Greb et al., 1998	Labatiuk et al., 1997
Notes	Investigated 45 precipitation events over a 9-month period. Percent removal rates reflect overall efficiency, accounting for pollutants in bypassed flows.	Data represent the mean percent removal rate for four storm events.
TSS[a]	21	51.5
TDS[a]	-21	-
TP[a]	17	-
DP[a]	17	-
Pb[a]	24	51.2
Zn[a]	17	39.1
Cu[a]	-	21.5
PAH[a]	32	-
NO_2+NO_3[a]	5	-

[a] TSS=total suspended solids; TDS=total dissolved solids; TP=total phosphorus; DP=dissolved phosphorus; Pb=lead; Zn=zinc; Cu=copper; PAH=polynuclear aromatic hydrocarbons; NO_2+NO_3=nitrite+nitrate-nitrogen

BUFFER ZONES
Description
An aquatic buffer is an area along a shoreline, wetland, or stream where development is restricted or prohibited. The primary function of aquatic buffers is to physically protect and separate a stream, lake, or wetland from future disturbance or encroachment. If properly designed, a buffer can provide storm water management and act as a right-of-way during floods, sustaining the integrity of stream ecosystems and habitats. Technically, aquatic buffers are one type of conservation area that function as an integral part of the aquatic ecosystem and can also function as part of an urban forest.
The three types of buffers are water pollution hazard setbacks, vegetated buffers, and engineered buffers. Water pollution hazard setbacks are areas that separate a potential pollution hazard from a waterway. By providing setbacks from these areas in the form of a buffer, the potential for pollution can be reduced. Vegetated buffers are any number of natural areas that exist to divide land uses or provide landscape relief. Engineered buffers are areas specifically designed to treat storm water before it enters into a stream, lake, or wetland.

Applicability

Buffers can be applied to new development by establishing specific preservation areas and sustaining management through easements or community associations. For existing developed areas, an easement may be needed from adjoining landowners. A local ordinance can help set specific criteria for buffers to achieve storm water management goals.

In many regions of the country, the benefits of buffers are amplified if they are managed in a forested condition. In some settings, buffers can remove pollutants traveling in storm water or ground water. Shoreline and stream buffers situated in flat soils have been found to be effective in removing sediment, nutrients, and bacteria from storm water runoff and septic system effluent in a wide variety of rural and agricultural settings along the East Coast and with some limited capability in urban settings. Buffers can also provide wildlife habitat and recreation, and can be reestablished in urban areas as part of an urban forest.

Siting and Design Considerations

There are ten key criteria to consider when establishing a stream buffer:

- Minimum total buffer width
- Three-zone buffer system
- Mature forest as a vegetative target
- Conditions for buffer expansion or contraction
- Physical delineation requirements
- Conditions where buffer can be crossed
- Integrating storm water and storm water management within the buffer
- Buffer limit review
- Buffer education, inspection, and enforcement
- Buffer flexibility.

In general, a minimum base width of at least 100 feet is recommended to provide adequate stream protection. The three-zone buffer system, consisting of inner, middle, and outer zones, is an effective technique for establishing a buffer. The zones are distinguished by function, width, vegetative target, and allowable uses. The inner zone protects physical and ecological integrity and is a minimum of 25 feet plus wetland and critical habitats. The vegetative target consists of mature forest, and allowable uses are very restricted (flood controls, utility right-of-ways, footpaths, etc.).

The middle zone provides distance between upland development and the inner zone and is typically 50 to 100 feet, depending on stream order, slope, and 100-year floodplain. The vegetative target for this zone is managed forest, and usage is restricted to some recreational uses, some storm water BMPs, and bike paths. The outer zone functions to prevent encroachment and filter backyard runoff. The width is at least 25 feet and, while forest is encouraged, turfgrass can be a vegetative target. Uses for the outer zone are unrestricted and can include lawn, garden, compost, yard wastes, and most storm water BMPs.

For optimal storm water treatment, the following buffer designs are recommended. The buffer should be composed of three lateral zones: a storm water depression area that leads to a grass filter strip that in turn leads to a forested buffer. The storm water depression is designed to capture and store storm water during smaller storm events and bypass larger stormflows directly into a channel. The captured runoff within the storm water depression can then be spread across a grass filter designed for sheetflow conditions for the water quality storm. The grass filter then discharges into a wider forest buffer designed to have zero discharge of surface runoff to the stream (i.e., full infiltration of sheetflow).

Stream buffers must be highly engineered in order to satisfy these demanding hydrologic and hydraulic conditions. In particular, simple structures are needed to store, split, and spread surface runoff within the storm water depression area. Although past efforts to engineer urban stream buffers were plagued by hydraulic failures and maintenance problems, recent experience with similar bioretention areas has been much more positive (Claytor and Schueler, 1996). Consequently, it may be useful to consider elements of bioretention design for the first zone of an urban stream buffer (shallow ponding depths, partial underdrains, drop inlet bypass, etc).

Limitations

Only a handful of studies have measured the ability of stream buffers to remove pollutants from storm water. One limitation is that urban runoff concentrates rapidly on paved and hard-packed turf surfaces and often crosses the buffer as channel flow, effectively shortcutting through the buffer. To achieve optimal pollutant removal, the engineered buffer should be carefully designed with a storm water depression area, grass filter, and forested strip.

Maintenance Considerations

An effective buffer management plan should include establishment, management, and distinctions of allowable and unallowable uses in the buffer zones. Buffer boundaries should be well defined and visible before, during, and after construction. Without clear signs or markers defining the buffer, boundaries become invisible to local governments, contractors, and residents. Buffers designed to capture storm water runoff from urban areas will require more maintenance if the first zone is designated as a bioretention or other engineered depression area.

Effectiveness

The pollutant removal effectiveness of buffers depends on the design of the buffer; while water pollution hazard setbacks are designed to prevent possible contamination from neighboring land uses, they are not designed for pollutant removal during a storm. With vegetated buffers, some pollutant removal studies have shown that they range widely in effectiveness (Table 1). Proper design of buffers can help increase the pollutant removal from storm water runoff (Table 2).

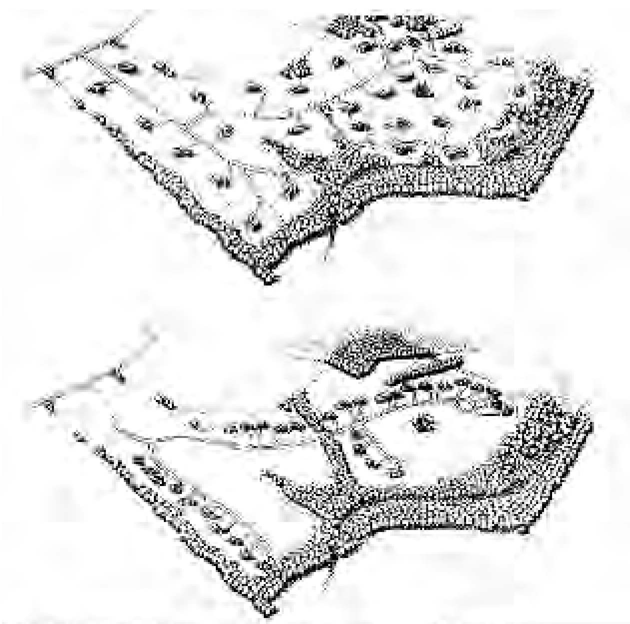
Table 1: Pollutant removal rates in buffer zones

Reference	Buffer Vegetation	Buffer Width (meters)	Total % TSS Removal	Total % Phosphorous Removal	Total % Nitrogen Removal
Dillaha et al., 1989	Grass	4.6–9.1	63–78	57–74	50–67
Magette et al., 1987	Grass	4.6–9.2	72–86	41–53	17–51
Schwer and Clausen, 1989	Grass	26	89	78	76
Lowrance et al., 1983	Native hardwood forest	20–40	–	23	–
Doyle et al., 1977	Grass	1.5	–	8	57
Barker and Young, 1984	Grass	79	–	–	99
Lowrance et al., 1984	Forested	–	–	30–42	85
Overman and Schanze, 1985	Grass	–	81	39	67

Table 2: Factors that enhance/reduce buffer pollutant removal performance

Factors that Enhance Performance	Factors that Reduce Performance
Slopes less than 5%	Slopes greater than 5%
Contributing flow lengths <150 feet.	Overland flow paths over 300 feet
Water table close to surface	Ground water far below surface
Check dams/level spreaders	Contact times less than 5 minutes
Permeable but not sandy soils	Compacted soils
Growing season	Nongrowing season
Long length of buffer or swale	Buffers less than 10 feet
Organic matter, humus, or mulch layer	Snowmelt conditions, ice cover
Small runoff events	Runoff events >2 year event.
Entry runoff velocity less than 1.5 feet/sec	Entry runoff velocity more than 5 feet/sec
Swales that are routinely mowed	Sediment buildup at top of swale
Poorly drained soils, deep roots	Trees with shallow root systems
Dense grass cover, 6 inches tall	Tall grass, sparse vegetative cover

OPEN SPACE DESIGN



A site developed using open space design principles (bottom) maintains more undeveloped common space than the conventional development plan (top) (Source: Arendt, 1996)

Description

Open space design, also known as conservation development or cluster development, is a better site design technique that concentrates dwelling units in a compact area in one portion of the development site in exchange for providing open space and natural areas elsewhere on the site. The minimum lot sizes, setbacks and frontage distances for the residential zone are relaxed in order to create the open space at the site. Open space designs have many benefits in comparison to the conventional subdivisions that they replace: they can reduce impervious cover, storm water pollutants, construction costs, grading, and the loss of natural areas. However, many communities lack zoning ordinances to permit open space development, and even those that have enacted ordinances might need to revise them to achieve greater water quality and environmental benefits.

The benefits of open space design can be amplified when it is combined with other better site design techniques such as narrow streets, open channels, and alternative turnarounds (see Narrower Residential Streets, Eliminating Curbs and Gutters, and Alternative Turnarounds).

Applicability

The codes and ordinances that govern residential development in many communities do not allow developers to build anything other than conventional subdivisions. Consequently, it may be necessary to enact a new ordinance or revise current development regulations to enable developers to pursue this design option. Model ordinances and regulations for open space design can be found on http://www.cwp.org and in *Better Site Design: A Handbook for Changing Development Rules in Your Community* (CWP, 1998).

Open space design is widely applicable to most forms of residential development. The greatest storm water and pollutant reduction benefits typically occur when open space design is applied to residential zones that have larger lots (less than two dwelling units per acre). In these types of large lot zones, a great deal of natural or community open space can be created by shrinking lot sizes. However, open space design may not always be a viable option for high-density residential zones, redevelopment, or infill development, where lots are small to begin with and clustering will yield little open space. In rural areas, open space design may need to be adapted, especially in communities where shared septic fields are not currently allowed by public health authorities.

Open space design can be employed in nearly all geographic regions of the country, with the result of different types of open space being conserved (forest, prairie, farmland, chaparral, or desert).

Siting and Design Conditions

Several site planning techniques have been proposed for designing effective open space developments (Arendt, 1996, and DE DNREC, 1997). Often, a necessary first step is adoption of a local ordinance that allows open space design within conventional residential zones. Such ordinances specify more flexible and smaller lot sizes, setbacks, and frontage distances for the residential zone, as well as minimum requirements for open space and natural area conservation. Other key elements of effective open space ordinances include requirements for the consolidation and use of open space, as well as enforceable provisions for managing the open space on a common basis.

Limitations

A number of real and perceived barriers hinder wider acceptance of open space designs by developers, local governments, and the general public. For example, despite strong evidence to the contrary, some developers still feel that open space designs are less marketable than conventional residential subdivisions. In other cases, developers contend that the review process for open space design is more lengthy, costly, and potentially controversial than that required for conventional subdivisions, and thus, not worth the trouble. Local governments may be concerned that homeowner associations lack the financial resources, liability insurance, or technical competence to maintain open space adequately. Finally, the general public is often suspicious of cluster or open space development proposals, feeling that they are a "Trojan Horse" for more intense development, traffic, and other local concerns. At the regional level, open space design policies and ordinances need to be carefully constructed and implemented so as not to lead to "leap-frogging," which is the creation of additional development in already built-up areas. An open space development that requires new infrastructure, such as roads, water and sewer lines, and commercial areas, can actually create more imperviousness at the regional level than it saves at the site level.

In reality, many of these misconceptions can be directly addressed through a clear open space ordinance and by providing training and incentives to the development and engineering community. The Natural Resources Defense Council presents several examples of successful conservation-oriented developments in *Stormwater Strategies: Community Responses to Runoff Pollution* (1999).

Maintenance Considerations

Once established, common open space and natural conservation areas must be managed by a responsible party able to maintain the areas in a natural state in perpetuity. Typically, the open space is protected by legally enforceable deed restrictions, conservation easements, and maintenance agreements. In most communities, the authority for managing open space falls to a homeowner or community association or a land trust. Annual maintenance tasks for open space managed as natural areas are almost non-existent, and the annual maintenance cost for managing an acre of natural area is less than $75 (CWP, 1998). It may be useful to develop a habitat plan for natural areas that may require periodic management actions.

Effectiveness

Recent redesign research indicates that open space design can provide impressive pollutant reduction benefits compared to the conventional subdivisions they replace. For example, the Center for Watershed Protection (1998) reported that nutrient export declined by 45 percent to 60 percent when two conventional subdivisions were redesigned as open space subdivisions. Other researchers have reported similar levels of pollutant reductions when conventional subdivisions were replaced by open space subdivisions (Maurer, 1996; DE DNREC, 1997; Dreher and Price, 1994; and SCCCL, 1995). In all cases, the reduction in pollutants was due primarily to the sharp drop in runoff caused by the lower impervious cover associated with open space subdivisions. In the redesign studies cited above, impervious cover declined by an average of 34 percent when open space designs were utilized.

Along with reduced imperviousness, open space designs provide a host of other environmental benefits lacking in most conventional designs. These developments reduce potential pressure to encroach on resource and buffer areas because enough open space is usually reserved to accommodate resource protection areas. As less land is cleared during the construction process, the potential for soil erosion is also greatly diminished. Perhaps most importantly, open space design reserves 25 to 50 percent of the development site in green space that would not otherwise be protected, preserving a greater range of landscapes and habitat "islands" that can support considerable diversity in mammals, songbirds, and other wildlife.

URBAN FORESTRY

Description

Urban forestry is the study of trees and forests in and around towns and cities. Since trees absorb water, patches of forest and the trees that line streets can help provide some of the storm water management required in an urban setting. Urban forests also help break up a landscape of impervious cover, provide small but essential green spaces, and link walkways and trails.

Successful urban forestry requires a conservation plan for individual trees as well as forest areas larger than 10,000 $feet^2$. A local forest or tree ordinance is one technique for achieving conservation, and when specific measures to protect and manage these areas are included, urban forests and trees can also help reduce storm water management needs in urban areas.

Applicability

From a stream preservation perspective, it is ideal to retain as much contiguous forest as possible. At the same time, this may not be an option in many urban areas. If forested areas are fragmented, it is ideal to retain the closest fragments together.

In rapidly urbanizing areas, where clearing and grading are important, tree preservation areas should be clearly marked. Delineating lines along a critical root zone (CRZ) rather than a straight line is essential to preserving trees and can help reduce homeowner complaints about tree root interference into sewer or septic lines.

Implementation

The concept of the CRZ is essential to a proper management plan. The CRZ is the area around a tree required for the tree's survival. Determined by the tree size and species, as well as soil conditions, for isolated specimen trees, the CRZ can be estimated as 1-1/2 feet of radial distance for every inch of tree diameter. In larger areas of trees, the CRZ of forests can be estimated at 1 foot of radial distance for every inch of tree diameter, or a minimum of 8 feet.

An urban forestry plan should include measures to establish, conserve, and/or reestablish preservation areas. A forest preservation ordinance is one way to set design standards outlining how a forest should be preserved and managed. The ordinance should outline some basic management techniques and should contain some essential elements. The following is a list of some typical elements of a forest conservation plan:

- A map and narrative description of the forest and the surrounding area that includes topography, soils, streams, current forested and unforested areas, tree lines, critical habitats, and 100-year flood plain.
- An assessment that establishes preservation, reforestation, and afforestation areas.
- A forest conservation map that outlines forest retention areas, reforestation, afforestation, protective devices, limits of disturbance, and stockpile areas.
- A schedule of any additional construction in and around the forest area.
- A specific management plan, including tree and forest protection measures.
- A reforestation and afforestation plan.

An ordinance can also be developed that addresses tree preservation at the site level both during construction and after construction is complete. This type of ordinance can be implemented on a smaller scale and can be integrated with a proposed development's erosion and sediment control and storm water pollution prevention plans, which many communities require of new developments.

American Forests, a non-profit organization dedicated to preserving and restoring forests in the United States, adopted an ecosystem restoration and maintenance agenda in 1999 to assist communities in planning and implementing tree and forest actions to restore and maintain healthy ecosystems and communities (American Forests, 2000). The agenda presents the organization's core values and policy goals as the basis for policy statements and as information to help community-based partners to prepare their own policy statements. Key policy goals include

- Increasing public and private sector investment in ecosystem restoration and maintenance activities
- Promoting an ecosystem workforce through training and apprenticeship programs and new job opportunities
- Building support for innovative monitoring systems to ensure collaborative learning and adaptive management
- Encouraging a "civic science" approach to ecosystem research that respects local knowledge, seeks community participation, and provides accessible information for communities.

Limitations

One of the biggest limitations to urban forestry is development pressure. Ordinances, conservation easements, and other techniques that are designed into a management program can help alleviate future development pressures. The size of the land may also limit the ability to protect individual trees. In these areas, a tree ordinance may be a more practical approach.

Forests may also harbor undesirable wildlife elements including insects and other pests. If forests border houses, this may be a concern for residents.

Maintenance Considerations

Maintenance considerations for urban forests may require fringe landscaping and trash pick-up. By using native vegetation and keeping the area as natural as possible, maintenance efforts can be minimized.

Effectiveness

There are numerous environmental and storm water benefits to urban forestry. These include the absorption of carbon dioxide by trees, reduction of temperature, and provision of habitat for urban wildlife. Urban forests can also act as natural storm water management areas by filtering particulate matter (pollutants, some nutrients, and sediment) and by absorption of water. Urban forestry also reduces noise levels, provides recreational benefits, and increases property values.

Urban forests and trees are known to have numerous environmental benefits, including pollutant removal. Trees can absorb water, pollutant gases, airborne particulates, sediment, nitrogen, phosphorous, and pesticides.

There are numerous economic benefits to urban forests, including proven increases in property values. In addition, by preserving trees and forests, clearing and grading as well as erosion and sediment costs are saved during construction. Maintenance costs are also minimized by keeping areas as natural as possible (Table 1).

Table 1: Annual maintenance costs of different types of green spaces (Adapted from Brown et al., 1998)

Land Use	**Approximate Annual Maintenance Costs**	**Source**
Natural Open Space: Only minimum maintenance, trash/debris cleanup	$75/acre/year	NPS, 1995
Lawns: Regular mowing	$270 to $240/acre/year	WHEC, 1992
Passive Recreation	$200/acre/year	NPS, 1995

ELIMINATING CURBS AND GUTTERS

Description

This better site design practice involves promoting the use of grass swales as an alternative to curbs and gutters along residential streets. Curbs and gutters are designed to quickly convey runoff from the street to the storm drain and, ultimately, to the local receiving water. Consequently, curbs and gutters provide little or no removal of storm water pollutants. Indeed, curbs often act as a pollutant trap where deposited pollutants are stored until they are washed out in the next storm. Many communities require curb and gutters as a standard element of their road sections, and discourage the use of grass swales. Revisions to current local road and drainage regulations are needed to promote greater use of grass swales along residential streets, in the appropriate setting. The storm water management and pollutant removal benefits of grass swales are documented in detail in the Grassed Swales fact sheet.

Applicability

The use of engineered swales in place of curbs and gutters should be encouraged in low- and medium-density residential zones where soils, slope and housing density permit. However, eliminating curbs and gutters is generally not feasible for streets with high traffic volume or extensive on-street parking demand (i.e., commercial and industrial roads), nor is it a viable option in arid and semi-arid climates where grass cannot grow without irrigation. Moreover, the use of grass swales may not be permitted by current local or state street and drainage standards.

Siting and Design Conditions

A series of site factors must be evaluated to determine whether a grass swale is a viable replacement for curbs and gutters at a particular site.

Contributing drainage area. Most individual swales cannot accept runoff from more than 5 acres of contributing drainage area, and typically serve 1–2 acres each.

Slope. Swales generally require a minimum slope of 1 percent and a maximum slope of 5 percent.

Soils. The effectiveness of swales is greatest when the underlying soils are permeable (hydrologic soil groups A and B). The swale may need more engineering if soils are less permeable.

Water Table. Swales should be avoided if the seasonally high water table is within 2 feet of the proposed bottom of the swale.

Development Density. The use of swales is often difficult when development density becomes more intense than four dwelling units per acre, simply because the number of driveway culverts increases to the point where the swale essentially becomes a broken-pipe system. Typically, grass swales are designed with a capacity to handle the peak flow rate from a 10-year storm, and fall below erosive velocities for a 2-year storm.

Limitations
A number of real and perceived limitations hinder the use of grass swales as an alternative to curb and gutters:

- *Snowplow operation can be more difficult without a defined road edge*. However, on the plus side, roadside swales increase snow storage at the road edge, and smaller snowplows may be adequate.
- *The pavement edge along the swale can experience more cracking and structural failure, increasing maintenance costs.* The potential for pavement failure at the road/grass interface can be alleviated by "hardening" the interface with grass pavers or geo-synthetics placed beneath the grass. Other options include placing a low-rising concrete strip along the pavement edge.
- *The shoulder and open channel will require more maintenance*. In reality, maintenance requirements for grass channels are generally comparable to those of curb and gutter systems. The major requirements involve turf mowing, debris removal, and periodic inspections.
- *Some grass swales can have standing water, which make them difficult to mow, and can cause nuisance problems such as odors, discoloration, and mosquitoes*. In reality, grass channels are not designed to retain water for any appreciable period of time, and the potential for snakes and other vermin can be minimized by frequent mowing.

Other concerns involve fears about utility installation and worries that the grass edge along the pavement will be torn up by traffic and parking. While utilities will need to be installed below the paved road surface instead of the right of way, most other concerns can frequently be alleviated through the careful design and integration of the open channels along the residential street. (Consult the Grassed Swales fact sheet for details on design variations that can reduce these problems.)

Maintenance Considerations
The major maintenance requirement for grass swales involves mowing during the growing season, a task usually performed by homeowners. In addition, sediment deposits may need to be removed from the bottom of the swale every ten years or so, and the swale may need to be tilled and re-seeded periodically. Occasionally, erosion of swale side slopes may need to be stabilized. The overall maintenance burden of grass swales is low in relation to other storm water practices, and is usually within the competence of the individual homeowner. The only major maintenance problem that might arise pertains to "problem" swales that have standing water and are too wet to mow. This particular problem is often alleviated by the installation of an underground storm drain system.

Effectiveness
Under the proper design conditions, grass swales can be effective in removing pollutants from urban storm water (Schueler, 1996). More information on the pollutant removal capability of various grass swale designs can be found in the Grassed Swales fact sheet.

GREEN PARKING

Description
Green parking refers to several techniques applied together to reduce the contribution of parking lots to the total impervious cover in a lot. From a storm water perspective, application of green parking techniques in the right combination can dramatically reduce impervious cover and, consequently, the amount of storm water runoff. Green parking lot techniques include setting maximums for the number of parking lots created, minimizing the dimensions of parking lot spaces, utilizing alternative pavers in overflow parking areas, using bioretention areas to treat storm water, encouraging shared parking, and providing economic incentives for structured parking.

Applicability
All of the green parking techniques can be applied in new developments and some can be applied in redevelopment projects, depending on the extent and parameters of the project. In urban areas, application of some techniques, like encouraging shared parking and providing economic incentives for structured parking, can be very practical and necessary. Commercial areas can have excessively high parking ratios, and application of green parking techniques in various combinations can dramatically reduce the impervious cover of a site.

Implementation
Many parking lot designs result in far more spaces than actually required. This problem is exacerbated by a common practice of setting parking ratios to accommodate the highest hourly parking during the peak season. By determining average parking demand instead, a lower maximum number of parking spaces can be set to accommodate most of the demand.
Table 1 provides examples of conventional parking requirements and compares them to average parking demand.

Table 1: Conventional minimum parking ratios (Source: ITE, 1987; Smith, 1984; Wells, 1994)

Land Use	**Parking Requirement**		**Actual Average Parking Demand**
	Parking Ratio	**Typical Range**	
Single family homes	2 spaces per dwelling unit	1.5–2.5	1.11 spaces per dwelling unit
Shopping center	5 spaces per 1000 ft^2 GFA	4.0–6.5	3.97 per 1000 ft^2 GFA
Convenience store	3.3 spaces per 1000 ft^2 GFA	2.0–10.0	--
Industrial	1 space per 1000 ft^2 GFA	0.5–2.0	1.48 per 1000 ft^2 GFA
Medical/ dental office	5.7 spaces per 1000 ft^2 GFA	4.5–10.0	4.11 per 1000 ft^2 GFA
GFA = Gross floor area of a building without storage or utility spaces.			

Another green parking lot technique is to minimize the dimensions of the parking spaces. This can be accomplished by reducing both the length and width of the parking stall. Parking stall dimensions can be further reduced if compact spaces are provided. While the trend toward larger sport utility vehicles (SUVs) is often cited as a barrier to implementing stall minimization technique, stall width requirements in most local parking codes are much larger than the widest SUVs (CWP, 1998).
Utilizing alternative pavers is also an effective green parking technique. They can replace conventional asphalt or concrete in both new developments and redevelopment projects. Alternative pavers can range from medium to relatively high effectiveness in meeting storm water quality goals. The different types of alternative pavers include gravel, cobbles, wood mulch, brick, grass pavers, turf blocks, natural stone, pervious concrete, and porous asphalt. In general, alternate pavers require proper installation and more maintenance than conventional asphalt or concrete. For more specific information on alternate pavers, refer to the Alternative Pavers fact sheet.
Bioretention areas can effectively treat storm water leaving a parking lot. Storm water is directed into a shallow, landscaped area and temporarily detained. The runoff then filters down through the bed of the facility and is infiltrated into the subsurface or collected into an underdrain pipe for discharge into a stream or another storm water facility. Bioretention facilities can be attractively integrated into landscaped areas and can be maintained by commercial landscaping firms. For detailed design specifications of bioretention areas, refer to the Bioretention fact sheet.
Shared parking in mixed-use areas and structured parking also are green parking techniques that can further reduce the conversion of land to impervious cover. A shared parking arrangement could include usage of the same parking lot by an office space that experiences peak parking demand during the weekday with a church that experiences parking demands during the weekends and evenings. Costs may dictate the usage of structured parking, but building upward or downward can help minimize surface parking.
Limitations
Some limitations to applying green parking techniques include applicability, cost, and maintenance. For example, shared parking is only practical in mixed use areas, and structured parking may be limited by the

cost of land versus construction. Alternative pavers are currently only recommended for overflow parking because of the considerable cost of maintenance. Bioretention areas increase construction costs.

The pressure to provide excessive parking spaces can come from fear of complaints as well as requirements of bank loans. These factors can pressure developers to construct more parking than necessary and present possible barriers to providing the greenest parking lot possible.

Effectiveness

Applied together, green parking techniques can effectively reduce the amount of impervious cover, help to protect local streams, result in storm water management cost savings, and visually enhance a site. Proper design of bioretention areas can help meet storm water management and landscaping requirements while keeping maintenance costs at a minimum.

Utilizing green parking lots can dramatically reduce the amount of impervious cover created. The level of the effectiveness depends on how much impervious cover is reduced as well as the combination of techniques utilized to provide the greenest parking lot. While the pollutant removal rates of bioretention areas have not been directly measured, their capability is considered comparable to a dry swale, which removes 91 percent of total suspended solids, 67 percent of total phosphorous, 92 percent of total nitrogen, and 80–90 percent of metals (Claytor and Schueler, 1996).

An excellent example of the multiple benefits of rethinking parking lot design is the Fort Bragg vehicle maintenance facility parking lot in North Carolina (NRDC, 1999). This redesign reduced impervious cover by 40 percent, increased parking by 20 percent, and saved $1.6 million (20 percent) on construction costs over the original, conventional design. Stormwater management features, such as detention basins located within grassed islands and an onsite drainage system that took advantage of existing sandy soils, were incorporated into the parking lot design as well.

Cost Considerations

Setting maximums for parking spaces, minimizing stall dimensions, and encouraging shared parking can result in considerable construction cost savings. At the same time, implementing green parking techniques can also reduce storm water management costs.

ALTERNATIVE TURNAROUNDS

Description

Alternative turnarounds are designs for end-of-street vehicle turnaround that replace cul-de-sacs and reduce the amount of impervious cover created in residential neighborhoods. Cul-de-sacs are local access streets with a closed circular end that allows for vehicle turnarounds. Many of these cul-de-sacs can have a radius of more than 40 feet. From a storm water perspective, cul-de-sacs create a huge bulb of impervious cover, increasing the amount of storm water runoff. For this reason, reducing the size of cul-de-sacs through the use of alternative turnarounds or eliminating them altogether can reduce the amount of impervious cover created at a site.

Numerous alternatives create less impervious cover than the traditional 40-foot cul-de-sac. These alternatives include reducing cul-de-sacs to a 30-foot radius and creating hammerheads, loop roads, and pervious islands in the cul-de-sac center.

Applicability

Alternative turnarounds can be applied in the design of residential, commercial, and mixed-use developments. Combined with alternative pavers, green parking, curb elimination, and other techniques, the total reduction to site impervious cover can be dramatic, reducing the amount of storm water runoff from the site. With proper designs, much of the remaining storm water can be treated on site.

Implementation

Sufficient turnaround area is a significant factor to consider in the design of cul-de-sacs. In particular, the types of vehicles entering into the cul-de-sac should be considered. Fire trucks, service vehicles, and school buses are often cited as examples for increased turning radii. However, research shows that some fire trucks are designed for smaller turning radii. In addition, many new larger service vehicles are designed using a tri-axle, and school buses usually do not enter individual cul-de-sacs.

Implementation of alternative turnarounds will also have to address local regulations and marketing issues. Communities may have specific design criteria for cul-de-sacs and other alternative turnarounds. Also, although cul-de-sacs are often featured as highly marketable, actual research on market preference is not widely available.

Limitations

Local regulations often dictate requirements for turnaround radii, and some of the alternatives may not be allowed by local codes. In addition, marketing perceptions may also dictate designs, particularly in residential areas. While changing local codes is no small effort, by initiating a local site planning roundtable, communities can change some of these regulations through a cluster ordinance or through a collective effort to review local codes to promote better site design.

Maintenance Considerations

If islands are constructed as part of a turnaround, these areas will need to be maintained. Kept as a natural area, the costs could be minimal. Bioretention areas will also require maintenance. The other options create less asphalt to repave, and maintenance will remain the same and cost less.

Effectiveness

In comparisons of several different turnaround options, hammerheads were found to create the least amount of impervious cover, as shown in Table 1.

Table 1. Impervious cover created by each turnaround option (Schueler, 1995)

Turnaround Option	**Impervious Area (square feet)**
40-foot radius	5,024
40-foot radius with island	4,397
30-foot radius	2,826
30-foot radius with island	2,512
Hammerhead	1,250

ALTERNATIVE PAVERS

Description

Alternative pavers are permeable surfaces that can replace asphalt and concrete and can be used for driveways, parking lots, and walkways. From a storm water perspective, this is important because alternative pavers can replace impervious surfaces, creating less storm water runoff. The two broad categories of alternative pavers are paving blocks and other surfaces, including gravel, cobbles, wood, mulch, brick, and natural stone. While porous pavement is an alternative paver, as an engineered storm water management practice it is discussed in detail in the Porous Pavement fact sheet.

Paving Blocks

Paving blocks are concrete or plastic grids with gaps between them. Paving blocks make the surface more rigid and gravel or grass planted inside the holes allows for infiltration. Depending on the use and soil types, a gravel layer can be added underneath to prevent settling and allow further infiltration.

Other Alternative Surfaces

Gravel, cobbles, wood, and mulch also allow varying degrees of infiltration. Brick and natural stone arranged in a loose configuration allow for some infiltration through the gaps. Gravel and cobbles can be used as driveway material, and wood and mulch can be used to provide walking trails.

Applicability

Alternative pavers can replace conventional asphalt or concrete in parking lots, driveways, and walkways. At the same time, traffic volume and type can limit application. For this reason, alternative pavers for parking are recommended only for overflow areas. In residential areas, alternative surfaces can be used for driveways and walkways, but are not ideal for areas that require handicap accessibility.

Siting and Design Criteria
Accessibility, climate, soil type, traffic volume, and long-term performance should be considered, along with costs and storm water quality controls, when choosing paving materials. Use of alternative pavers in cold climates will require special consideration, as snow shovels are not practical for many of these surfaces. Sand is particularly troublesome if used with paving blocks, as the sand that ends up between the blocks cannot effectively wash away or be removed. In addition, salt used to de-ice can also infiltrate directly into the soil and cause potential ground water pollution.
Soil types will affect the infiltration rates and should be considered when using alternative pavers. Clayey soils (D soils) will limit the infiltration on a site. If ground water pollution is a concern, use of alternative pavers with porous soils should be carefully considered.
The durability and maintenance cost of alternative pavers also limits use to low-traffic-volume areas. At the same time, alternative pavers can abate storm water management costs. Used in combination with other better-site-design techniques, the cumulative effect on storm water can be dramatic.
Limitations
Alternative pavers are not recommended for high-traffic volumes for durability reasons. Access for wheelchairs is limited with alternative pavers. In addition, snow removal is difficult since plows cannot be used, sand can cause the system to clog, and salt can be a potential pollutant.
Maintenance Considerations
Alternative pavers require periodic maintenance, and costs increase when the permeable surface must be restored.
Effectiveness
The most obvious benefit of utilizing alternative pavers includes reduction or elimination of other storm water management techniques. Applied in combination with other techniques such as bioretention and green parking, pollutant removal and storm water management can be further improved. (see Bioretention and Green Parking fact sheets for more information.)
Alternative pavers all provide better water quality improvement than conventional asphalt or concrete, and the range of improvement depends on the type of paver used. Table 1 provides a list of pavers and the range of water quality improvement achievable by different types of alternative pavers.

Table 1. Water quality improvement of various pavers (Source: BASMAA, 1997)

Material	**Water Quality Effectiveness**
Conventional Asphalt/ Concrete	Low
Brick (in a loose configuration)	Medium
Natural Stone	Medium
Gravel	High
Wood Mulch	High
Cobbles	Medium

WATER QUALITY UNITS – HYDRODYNAMIC SEPERATION
Description
These are water quality units that use hydrodynamic separators to effectively remove finer sediment, oil and grease, and floating and sinking debris. They are usually multi chambered structures made from concrete or HDPE materials.
Applicability
Storm water quality units are compact and easily installed at most sites. Sites with a very high concentration of pollutants may need a specialized design to deal with the abnormal levels of pollution. Most sites within the HCMA would be public parking areas with a minimum level of pollutants and standard water quality units would function well.
Siting and Design Considerations

Since these units require hydrodynamic action, the site grading is very important. Like detention/swales, too much grade could allow the storm water to be pushed through the unit too quickly without full treatment. If the grade was too flat, the unit could fail to properly treat the storm runoff from lack of hydrodynamic action. Large sites may create more runoff than one unit can handle and the site may need to be broken into several sections or drainage-sheds. Multiple units can usually be set in series to handle the flows. Attention should be paid to the location of the unit as large vactor trucks will need access to the unit on a regular basis for cleaning. The units should be kept as shallow as possible for cleaning and inspection purposes.

Limitations

These units require annual inspection by personnel who must be trained on what to look for during inspections. Failure to maintain the units regularly can result in failure of the unit and dischare of the captured pollutants. In areas near gravel parking lots or roads, increased maintenance may be required due to large sediment loading from the gravel areas. Access and machinery required for maintenance limit the location of the structure and high ground water may make installation more expensive. Being underground units with little of the structure being visible, these units may become 'forgotten'. Since the units are pre manufactured, large units require increased coordination during construction due to the size and weight of the units. These units do not provide for detention of the runoff, just treatment.

Maintenance Considerations

It is important that annual or more frequent inspection occur and that routine maintenance and nonroutine repair of storm water BMPs be done according to schedule or as soon as a problem is discovered. Because many BMPs are rendered ineffective for runoff control if not installed and maintained properly, it is essential that maintenance schedules are maintained and repairs are made promptly. In fact, some cases of BMP neglect can have detrimental effects on the landscape and increase the potential for erosion.

Effectiveness

The effectiveness of BMP inspection will be a function of the familiarity of the inspector with each particular BMP's location, design specifications, maintenance procedures, and performance expectations. Documentation should be kept regarding the dates of inspection, findings, and maintenance and repairs that result from the findings of an inspector. Such records are helpful in maintaining an efficient inspection and maintenance schedule and providing evidence of ongoing inspection and maintenance.

BMP INSPECTION AND MAINTENANCE

Description

To maintain the effectiveness of post construction storm water control best management practices (BMPs), regular inspection of control measures is essential. Generally, inspection and maintenance of BMPs can be categorized into two groups—expected routine maintenance and nonroutine (repair) maintenance. Routine maintenance refers to checks performed on a regular basis to keep the BMP in good working order and aesthetically pleasing. In addition, routine inspection and maintenance is an efficient way to prevent potential nuisance situations (odors, mosquitoes, weeds, etc.), reduce the need for repair maintenance, and reduce the chance of polluting storm water runoff by finding and correcting problems before the next rain.

In addition to maintaining the effectiveness of storm water BMPs and reducing the incidence of pests, proper inspection and maintenance is essential to avoid the health and safety threats inherent in BMP neglect (Skupien, 1995). The failure of structural storm water BMPs can lead to downstream flooding, causing property damage, injury, and even death.

Applicability

Under the proposed Storm Water Phase II rule, owners and operators of small municipal separate storm sewer system (MS4) facilities would be responsible for implementing BMP inspection and maintenance programs and having penalties in place to deter infractions (USEPA, 1999). All storm water BMPs should be inspected for continued effectiveness and structural integrity on a regular basis. Generally, all BMPs should be checked after each storm event in addition to these regularly scheduled inspections. Scheduled inspections will vary among BMPs. Structural BMPs such as storm drain drop inlet protection may require more frequent inspection to ensure proper operation. During each inspection, the inspector should document whether the

BMP is performing correctly, any damage to the BMP since the last inspection, and what should be done to repair the BMP if damage has occurred.

Siting and Design Considerations

In the case of vegetative or other infiltration BMPs, inspection of storm water management practices following a storm event should occur after the expected drawdown period for a given BMP. This allows the inspector to see whether detention and infiltration devices are draining correctly.

Inspection checklists should be developed for use by BMP inspectors. Checklists might include each BMP's minimum performance expectations, design criteria, structural specifications, date of implementation, and expected life span. In addition, the maintenance requirements for each BMP should be listed on the inspection checklist. This will aid the inspector in determining whether a BMP's maintenance schedule is adequate or needs revision. Also, a checklist will help the inspector determine renovation or repair needs.

Limitations

Routine maintenance materials such as shovels, lawn mowers, and fertilizer may be easily obtained on short notice with little effort. Unfortunately, not all materials that may be needed for emergency structural repairs are obtained with such ease. Thought should be given to stockpiling essential materials in case immediate repairs must be made to safeguard against property loss and to protect human health.

Maintenance Considerations

It is important that routine maintenance and nonroutine repair of storm water BMPs be done according to schedule or as soon as a problem is discovered. Because many BMPs are rendered ineffective for runoff control if not installed and maintained properly, it is essential that maintenance schedules are maintained and repairs are made promptly. In fact, some cases of BMP neglect can have detrimental effects on the landscape and increase the potential for erosion. However, "routine" maintenance, such as mowing grasses, should be flexible enough to accommodate the fluctuations in need based on relative weather conditions. For example, more harm than good may be caused by mowing during an extremely dry period or immediately following a storm event.

Effectiveness

The effectiveness of BMP inspection will be a function of the familiarity of the inspector with each particular BMP's location, design specifications, maintenance procedures, and performance expectations.

Documentation should be kept regarding the dates of inspection, findings, and maintenance and repairs that result from the findings of an inspector. Such records are helpful in maintaining an efficient inspection and maintenance schedule and providing evidence of ongoing inspection and maintenance.

Because maintenance work for storm water BMPs is usually not technically complicated (mowing, removal of sediment, etc.), workers can be drawn from a large labor pool. As structural BMPs increase in their sophistication, however, more specialized maintenance training might be needed to sustain BMP effectiveness.

Construction Storm Water Runoff Control

Updated July 2008; February 2010

Storm water from construction sites has the potential for having significant negative effects on local waterways. Pollutants normally associated with construction sites could include sediment, construction debris and chemicals, oil, grease, fertilizer and pesticides. The function of this measure would be to limit the negative impact of construction activity to adjacent waterways through various means including:

1. Proper site planning that minimizes impacts to the site.
2. Cooperating with state and local agencies.
3. Include appropriate BMPs into construction documents.
4. Construction activity inspection by Metroparks field staff to ensure BMP compliance.
5. Enforcement of BMP compliance within construction document provisions.

The Metroparks does not have regulatory powers or ability to implement ordinances, but will ensure compliance with all state and local ordinances and regulations regarding Metroparks owned and operated facilities and construction projects undertaken by the Metroparks. All development planning, engineering and construction activity that occurs with the Metroparks is administered and supervised by staff of the Metroparks Planning and Engineering Departments. In addition, construction plans are routinely submitted for site plan review to the local community having jurisdiction near that particular Metropark. At each construction site, Metropark staff from the Engineering or Planning Departments is routinely on site overseeing the construction activities and monitoring compliance with the job specifications, contract documents and local ordinance. In addition, the Metroparks also employees a certified storm water operator. Whether the construction activities are carried out through a contract or by park forces, there is a high degree of control during the construction process which will help ensure compliance of storm water BMP applications.

Current and past practice in the Metroparks for the design and construction of roads, lots and site developments has typically incorporated turf or vegetative swales for drainage of storm water runoff. This practice is made possible due to the typically generous land areas available for development within the Metroparks. These vegetative swales aid in minimizing impacts of the adjacent construction activity. The use of catch basins and culverts for storm water conveyance is typically limited to intensively developed areas such as parking lots and plazas associated with pool and play activity areas. Projects involving earthwork or site development incorporate soil erosion control measures in accordance with the Soil Erosion Act, PA 451 of 1994. The development and implementation of BMPs is a critical component of the measure. In order to facilitate the implementation process, the Metroparks will initiate the use of EPA NPDES BMP guidelines in this pollution prevention process as indicated at the end of this document and/or develop specific Metroparks BMPs as appropriate.

Task: To provide and implement storm water runoff controls which will minimize or prevent negative impacts on water quality from construction activity. These measures will be based on current best available technology and field experience.

Description: 1. The Metroparks will incorporate storm water management BMPs in the design and construction of new projects on Metroparks properties. Adequate space will be allotted for temporary soil erosion and sedimentation controls during constructions as well as permanent control measures as appropriate.

2. The Metroparks and its contractors will comply with all soil erosion control measures in accordance with the Soil Erosion Act, Pa. 451 of 1994. The Metroparks and its contractors will, when required, submit its plans for local site plan review and will subsequently comply with all local ordinances.

3. Project supervision by Metroparks staff will be in place for all construction activity to ensure contract document and regulation compliance.

4. Where appropriate and feasible, the Metroparks and its contractors will implement storm water BMPs to minimize potential water quality impact of construction. These BMPs would include:

- Minimizing vegetation clearing and preserving natural vegetation within the project site.
- Using check dams, filter berms and grass-lined channels, detention ponds and wetland systems to control run-off.
- Using mulch, temporary and permanent seeding or sodding to stabilize exposed soils.
- Installation of diversion dikes, silt fence, sediment basins, sediment traps and sediment chambers and sediment filters at storm drain inlets.
- The use of mulch and geotextiles to protect steep slopes.
- Maintaining vegetative buffers along waterways.
- Employ dust control methods during construction.

5. The Metroparks will ensure that it and its' contractors will properly dispose of and control waste products generated from the construction process, including but not necessarily limited to demolition and construction debris, concrete truck washout, chemicals, litter, fertilizer, pesticides and sanitary waste at the construction site that may adversely impact water quality.

6. Proper notification will be given to the appropriate Soil Erosion and Sedimentation Control Agency and the MDNRE within 24 hours, if a construction activity results is a deposit or imminent threat to deposit solids or other waste materials into the drainage system that is determined by the Metroparks Certified Storm Water Operator, may endanger public health or the environment and will be reported in accordance with Part 1.C.2.a. of the general permit.

Responsibility: The Metroparks Planning and Engineering Departments are responsible for administration and implementation of the SWMPP. Information, complaints or other feedback from the public regarding construction site storm water management can be addressed at any park facility, park office, via e-mail to the Metroparks web site or toll free phone number to the Metroparks. All inquiries will be directed to Michael Arens, Chief Engineer and administrator for the Metroparks Phase II Storm Water Management Program Plan.

CONSTRUCTION STORM WATER RUNOFF CONTROL - BEST MANAGEMENT PRACTICES (BMPS)

Updated July 2008; February 2010

LAND GRADING

Description

Land grading involves reshaping the ground surface to planned grades as determined by an engineering survey, evaluation, and layout. Land grading provides more suitable topography for buildings, facilities, and other land uses and helps to control surface runoff, soil erosion, and sedimentation during and after construction.

Applicability

Land grading is applicable to sites with uneven or steep topography or easily erodible soils, because it stabilizes slopes and decreases runoff velocity. Grading activities should maintain existing drainage patterns as much as possible.

Site and Design Considerations

Before grading activities begin, decisions must be made regarding the steepness of cut-and-fill slopes and how the slopes will be

- Protected from runoff
- Stabilized
- Maintained

A grading plan should be prepared that establishes which areas of the site will be graded, how drainage patterns will be directed, and how runoff velocities will affect receiving waters. The grading plan also includes information regarding when earthwork will start and stop, establishes the degree and length of finished slopes, and dictates where and how excess material will be disposed of (or where borrow materials will be obtained if needed). Berms, diversions, and other storm water practices that require excavation and filling also should be incorporated into the grading plan.

A low-impact development BMP that can be incorporated into a grading plan is *site fingerprinting*, which involves clearing and grading only those areas necessary for building activities and equipment traffic. Maintaining undisturbed temporary or permanent buffer zones in the grading operation provides a low-cost sediment control measure that will help reduce runoff and off-site sedimentation. The lowest elevation of the site should remain undisturbed to provide a protected storm water outlet before storm drains or other construction outlets are installed.

Limitations

Improper grading practices that disrupt natural storm water patterns might lead to poor drainage, high runoff velocities, and increased peak flows during storm events. Clearing and grading of the entire site without vegetated buffers promotes off-site transport of sediments and other pollutants. The grading plan must be designed with erosion and sediment control and storm water management goals in mind; grading crews must be carefully supervised to ensure that the plan is implemented as intended.

Maintenance Considerations

All graded areas and supporting erosion and sediment control practices should be periodically checked, especially after heavy rainfalls. All sediment should be removed from diversions or other storm water conveyances promptly. If washouts or breaks occur, they should be repaired immediately. Prompt maintenance of small-scale eroded areas is essential to prevent these areas from becoming significant gullies.

Effectiveness

Land grading is an effective means of reducing steep slopes and stabilizing highly erodible soils when properly implemented with storm water management and erosion and sediment control practices. Land grading is not effective when drainage patterns are altered or when vegetated areas on the perimeter of the site are destroyed.

PRESERVING NATURAL VEGETATION

Description

The principal advantage of preserving natural vegetation is the protection of desirable trees, vines, bushes, and grasses from damage during project development. Vegetation provides erosion control, storm water detention, biofiltration, and aesthetic values to a site during and after construction activities. Other benefits from preserving natural areas are because natural vegetation

- Can process higher quantities of storm water runoff than newly seeded areas
- Does not require time to establish
- Has a higher filtering capacity than newly planted vegetation because aboveground and root structures are typically denser
- Reduces storm water runoff by intercepting rainfall, promoting infiltration, and lowering the water table through transpiration
- Provides buffers and screens against noise and visual disturbance
- Provides a fully developed habitat for wildlife
- Usually requires less maintenance (e.g., irrigation, fertilizer) than planting new vegetation
- Enhances aesthetics.

Applicability

Preservation of natural vegetation is applicable to all construction sites where vegetation exists in the predevelopment condition. Areas where preserving vegetation can be particularly beneficial are floodplains, wetlands, stream banks, steep slopes, and other areas where erosion controls would be difficult to establish, install, or maintain. Only land needed for building activities and vehicle traffic needs to be cleared.

Siting and Design Considerations

Vegetation should be marked for preservation before clearing activities begin. A site map should be prepared with the locations of trees and boundaries of environmentally sensitive areas and buffer zones to be preserved. The location of roads, buildings, and other structures can be planned to avoid these areas. Preservation requires careful site management to minimize the impact of construction activities on existing vegetation. Large trees located near construction zones should be protected because damage during construction activities may result in reduced vigor or death after construction has ceased. The boundaries around contiguous natural areas and tree drip lines should be extended and marked to protect the root zone from damage. Although direct contact by equipment is an obvious means of damage to trees and other vegetation, compaction, filling, or excavation of land too close to the vegetation also can cause severe damage.

When selecting trees for preservation, the following factors should be considered:

- *Tree vigor*. Preserving healthy trees that will be less susceptible to damage, disease, and insects. Indicators of poor vigor include dead tips of branches, stunted leaf growth, sparse foliage, and pale foliage color. Hollow, rotten, split, cracked, or leaning trees also have less chance of survival.
- *Tree age.* Older trees are more aesthetically pleasing as long as they are healthy.
- *Tree species.* Species well-suited to present and future site conditions should be chosen. Preserving a mixture of evergreens and hardwoods can help to conserve energy when evergreens are preserved on the northern side of the site to protect against cold winter winds and deciduous trees are preserved on the southern side to provide shade in the summer and sunshine in the winter.
- *Wildlife benefits.* Trees that are preferred by wildlife for food, cover, and nesting should be chosen.

Other considerations include following natural contours and maintaining preconstruction drainage patterns. Alteration of hydrology might result in dieoff of preserved vegetation because their environmental requirements are no longer met.

The following are basic considerations for preservation of natural vegetation:

- Boards should not be nailed to trees during building operations.
- Tree roots inside the tree drip line should not be cut.
- Barriers should be used to prevent the approach of equipment within protected areas.

- Equipment, construction materials, topsoil, and fill dirt should not be placed within the limit of preserved areas.
- If a tree or shrub that is marked for preservation is damaged, it should be removed and replaced with a tree of the same or similar species with a 2-inch or larger caliper width from balled and burlaped nursery stock when construction activity is complete.
- During final site cleanup, barriers around preserved areas and trees should be removed.

Limitations

Preservation of vegetation is limited by the extent of existing vegetation in preconstruction conditions. It requires planning to preserve and maintain the existing vegetation. It is also limited by the size of the site relative to the size of structures to be built. High land prices might prohibit preservation of natural areas. Additionally, equipment must have enough room to maneuver; in some cases preserved vegetation might block equipment traffic and may constrict the area available for construction activities. Finally, improper grading of a site might result in changes in environmental conditions that result in vegetation dieoff. Consideration should be given to the hydrology of natural or preserved areas when planning the site.

Maintenance Considerations

Even if precautions are taken, some damage to protected areas may occur. In such cases, damaged vegetation should be repaired or replaced immediately to maintain the integrity of the natural system. Continued maintenance is needed to ensure that protected areas are not adversely impacted by new structures. Newly planted vegetation should be planned to enhance the existing vegetation.

Effectiveness

Natural vegetation (existing trees, vines, brushes, and grasses) can provide water quality benefits by intercepting rainfall, filtering storm water runoff, and preventing off-site transport of sediments and other pollutants.

CHECK DAMS

Description

Check dams are small, temporary dams constructed across a swale or channel. Check dams can be constructed using gravel, rock, sandbags, logs, or straw bales and are used to slow the velocity of concentrated flow in a channel. By reducing the velocity of the water flowing through a swale or channel, check dams reduce the erosion in the swale or channel. As a secondary function, check dams can also be used to catch sediment from the channel itself or from the contributing drainage area as storm water runoff flows through the structure. However, the use of check dams in a channel should not be a substitute for the use of other sediment-trapping and erosion control measures. As with most other temporary structures, check dams are most effective when used in combination with other storm water and erosion and sediment control measures.

Applicability

Check dams should be used in swales or channels that will be used for a short period of time where it is not practical to line the channel or implement other flow control practices (USEPA, 1993). In addition, check dams are appropriate where temporary seeding has been recently implemented but has not had time to take root and fully develop.

Check dams are usually used in small open channels with a contributing drainage area of 2 to 10 acres. For a given swale or channel, multiple check dams, spaced at appropriate intervals, can increase overall effectiveness. If dams are used in a series, they should be spaced such that the base of the upstream dam is at the same elevation as the top of the next downstream dam (VDCR, 1995).

Site and Design Considerations

Check dams can be constructed from a number of different materials. Most commonly, they are made of rock, logs, sandbags, or straw bales. When using rock or stone, the material diameter should be 2 to 15 inches. Logs should have a diameter of 6 to 8 inches. Regardless of the material used, careful construction of a check dam is necessary to ensure its effectiveness. Dams should be installed with careful placement of the construction material. Mere dumping of the dam material into a channel is not appropriate and will reduce overall effectiveness.

All check dams should have a maximum height of 3 feet. The center of the dam should be at least 6 inches lower than the edges. This design creates a weir effect that helps to channel flows away from the banks and prevent further erosion. Additional stability can be achieved by implanting the dam material approximately 6 inches into the sides and bottom of the channel (VDCR, 1995). When installing more than one check dam in a channel, outlet stabilization measures should be installed below the final dam in the series. Because this area is likely to be vulnerable to further erosion, riprap, geotextile lining, or some other stabilization measure is highly recommended.

Limitations

Check dams should not be used in live, flowing streams unless approved by an appropriate regulatory agency (USEPA, 1992; VDCR, 1995). Because the primary function of check dams is to slow runoff in a channel, they should not be used as a stand-alone substitute for other sediment-trapping devices. Also, leaves have been shown to be a significant problem by clogging check dams in the fall. Therefore, they might necessitate increased inspection and maintenance.

Maintenance Considerations

Check dams should be inspected after each storm event to ensure continued effectiveness. During inspection, large debris, trash, and leaves should be removed. The center of a check dam should always be lower than its edges. If erosion or heavy flows cause the edges of a dam to fall to a height equal to or below the height of the center, repairs should be made immediately. Accumulated sediment should be removed from the upstream side of a check dam when the sediment has reached a height of approximately one-half the original height of the dam (measured at the center). In addition, all accumulated sediment should also be removed prior to removing a check dam. Removal of a check dam should be completed only after the contributing drainage area has been completely stabilized. Permanent vegetation should replace areas from which gravel, stone, logs, or other material have been removed. If the check dam is constructed of rock or gravel, maintenance crews should be sure to clear all small rock and gravel pieces from vegetated areas before attempting to mow the grass between check dams. Failure to remove stones and gravel can result in serious injury from flying debris.

Effectiveness

Field experience has shown that rock check dams are more effective than silt fences or straw bales to stabilize wet-weather ditches (VDCR, 1995). For long channels, check dams are most effective when used in a series, creating multiple barriers to sediment-laden runoff.

FILTER BERMS

Description

A gravel or stone filter berm is a temporary ridge made up of loose gravel, stone, or crushed rock that slows, filters, and diverts flow from an open traffic area and acts as an efficient form of sediment control. A specific type of filter berm is the continuous berm, a geosynthetic fabric that encapsulates sand, rock, or soil.

Applicability

Gravel or stone filter berms are most suitable in areas where vehicular traffic needs to be rerouted because roads are under construction, or in traffic areas within a construction site.

Siting and Design Considerations

The following construction guidelines should be considered when building the berm:

- Well-graded gravel or crushed rock should be used to build the berm.
- Berms should be spaced according to the steepness of the slope, with berms spaced closer together as the slope increases.
- Sediment that builds up should be removed and disposed of and the filter material should be replaced. Regular inspection should indicate the frequency of sediment removal needed.

Limitations

Berms are intended to be used only in gently sloping areas. They do not last very long, and they require maintenance due to clogging from mud and soil on vehicle tires.

Maintenance Considerations
The berm should be inspected after every rainfall to ensure that sediment has not built up and that no damage has been done by vehicles. It is important that repairs be performed at the first sign of deterioration to ensure that the berm is functioning properly.
Effectiveness
The effectiveness of a rock filter berm depends upon rock size, slope, soil, and rainfall amount. The continuous berm is not staked into the ground and no trenching is required. Effectiveness has been rated at up to 95 percent for sediment removal, but is highly dependent on local conditions including hydrologic, hydraulic, topographic, and sediment characteristics.

GRASS-LINED CHANNELS
Description
Grass-lined channels convey storm water runoff through a stable conduit. Vegetation lining the channel reduces the flow velocity of concentrated runoff. Grassed channels usually are not designed to control peak runoff loads by themselves and are often used in combination with other BMPs, such as subsurface drains and riprap stabilization.
Where moderately steep slopes require drainage, grassed channels can include excavated depressions or check dams to enhance runoff storage, decrease flow rates, and enhance pollutant removal. Peak discharges can be reduced through temporary detention in the channel. Pollutants can be removed from storm water by filtration through vegetation, by deposition, or in some cases by infiltration of soluble nutrients into the soil. The degree of pollutant removal in a channel depends on the residence time of water in the channel and the amount of contact with vegetation and the soil surface. As a result, removal efficiency is highly dependent on local conditions.
Applicability
Grassed channels should be used in areas where erosion-resistant conveyances are needed, including areas with highly erodible soils and moderately steep slopes (although less than 5 percent). They should only be installed where space is available for a relatively large cross section. Grassed channels have a limited ability to control runoff from large storms and should not be used in areas where flow rates exceed 5 feet per second.
Siting and Design Considerations
Grass-lined channels should be sited in accordance with the natural drainage system and should not cross ridges. The channel design should not have sharp curves or significant changes in slope. The channel should not receive direct sedimentation from disturbed areas and should be sited only on the perimeter of a construction site to convey relatively clean storm water runoff. Channels should be separated from disturbed areas by a vegetated buffer or other BMP to reduce sediment loads.
Basic design recommendations for grassed channels include the following:

- Construction and vegetation of the channel should occur before grading and paving activities begin.
- Design velocities should be less than 5 feet per second.
- Geotextiles can be used to stabilize vegetation until it is fully established.
- Covering the bare soil with sod, mulches with netting, or geotextiles can provide reinforced storm water conveyance immediately.
- Triangular-shaped channels are used with low velocities and small quantities of runoff; parabolic grass channels are used for larger flows and where space is available; trapezoidal channels are used with large flows of low velocity (low slope).
- Outlet stabilization structures should be installed if the runoff volume or velocity has the potential to exceed the capacity of the receiving area.
- Channels should be designed to convey runoff from a 10-year storm without erosion.
- The sides of the channel should be sloped less than 2:1, and triangular-shaped channels along roads should be sloped 2:1 or less for safety.
- All trees, brushes, stumps, and other debris should be removed during construction.

Effectiveness
Grass-lined channels can effectively transport storm water from construction areas if they are designed for expected flow rates and velocities and if they do not receive sediment directly from disturbed areas.
Limitations
Grassed channels, if improperly installed, can alter the natural flow of surface water and have adverse impacts on downstream waters. Additionally, if the design capacity is exceeded by a large storm event, the vegetation might not be sufficient to prevent erosion and the channel might be destroyed. Clogging with sediment and debris reduces the effectiveness of grass-lined channels for storm water conveyance.
Maintenance Considerations
Maintenance requirements for grass channels are relatively minimal. During the vegetation establishment period, the channels should be inspected after every rainfall. Other maintenance activities that should be carried out after vegetation is established are mowing, litter removal, and spot vegetation repair. The most important objective in the maintenance of grassed channels is the maintaining of a dense and vigorous growth of turf. Periodic cleaning of vegetation and soil buildup in curb cuts is required so that water flow into the channel is unobstructed. During the growing season, channel grass should be cut no shorter than the level of design flow.

RIPRAP
Description
Riprap is a permanent, erosion-resistant layer made of stones. It is intended to protect soil from erosion in areas of concentrated runoff. Riprap may also be used to stabilize slopes that are unstable because of seepage problems.
Applicability
Riprap can be used to stabilize cut-and-fill slopes; channel side slopes and bottoms; inlets and outlets for culverts, bridges, slope drains, grade stabilization structures, and storm drains; and streambanks and grades.
Siting and Design Considerations
Riprap may be unstable on very steep slopes, especially when rounded rock is used. For slopes steeper than 2:1, consider using materials other than riprap for erosion protection. If riprap is being planned for the bottom of a permanently flowing channel, the bottom can be modified to enhance fish habitat. This can be done by constructing riffles and pools which simulate natural conditions. These riffles promote aeration and the pools provide deep waters for habitats.
The following are some design recommendations for riprap installation, (Smolen et al., 1988):

- *Gradation*. A well-graded mixture of rock sizes should be used instead of one uniform size.
- *Quality of stone*. Riprap must be durable so that freeze/thaw cycles do not decompose it in a short time; most igneous stones such as granite have suitable durability.
- *Riprap depth*. The thickness of riprap layers should be at least 2 times the maximum stone diameter.
- *Filter material*. Filter material is usually required between riprap and the underlying soil surface to prevent soil from moving through the riprap; a filter cloth material or a layer of gravel is usually used for the filter.
    - *Leaching Protection*. Leaching can be controlled by installing a riprap gradation small enough to act as a filter against the channel base material, or a protective filter can be installed between the riprap and the base material.
    - *Riprap Limits*. The riprap should extend for the maximum flow depth, or to a point where vegetation will be satisfactory to control erosion.
    - *Curves*. Riprap should extend to five times the bottom width upstream and downstream of the beginning and ending of the curve as well as the entire curved section.
    - *Riprap Size*. The size of riprap to be installed depends on site-specific conditions.

Limitations
Riprap is limited by steepness of slope, because slopes greater than 2:1 have potential riprap loss due to erosion and sliding. When working within flowing streams, measures should be taken to prevent excessive

turbidity and erosion during construction. Bypassing base flows or temporarily blocking base flows are two possible methods.

Effectiveness

When properly designed and installed, riprap can prevent virtually all erosion from the protected area.

Maintenance Considerations

Riprap should be inspected annually and after major storms. If riprap has been damaged, repairs should be made promptly to prevent a progressive failure. If repairs are needed repeatedly at one location, the site should be evaluated to determine if the original design conditions have changed. Channel obstructions such as trees and sediment bars can change flow patterns and cause erosive forces that may damage riprap. Control of weed and brush growth may be needed in some locations.

MULCHING

Description

Mulching is a temporary erosion control practice in which materials such as grass, hay, wood chips, wood fibers, straw, or gravel are placed on exposed or recently planted soil surfaces. Mulching is highly recommended as a stabilization method and is most effective when used in conjunction with vegetation establishment. In addition to stabilizing soils, mulching can reduce storm water runoff velocity. When used in combination with seeding or planting, mulching can aid plant growth by holding seeds, fertilizers, and topsoil in place, preventing birds from eating seeds, retaining moisture, and insulating plant roots against extreme temperatures.

Mulch mattings are materials such as jute or other wood fibers that are formed into sheets and are more stable than loose mulch. Jute and other wood fibers, plastic, paper, or cotton can be used individually or combined into mats to hold mulch to the ground. Netting can be used to stabilize soils while plants are growing, although netting does not retain moisture or insulate against extreme temperatures. Mulch binders consist of asphalt or synthetic materials that are sometimes used instead of netting to bind loose mulches.

Applicability

Mulching is often used in areas where temporary seeding cannot be used because of environmental constraints. Mulching can provide immediate, effective, and inexpensive erosion control. On steep slopes and critical areas such as waterways, mulch matting is used with netting or anchoring to hold it in place. Mulches can be used on seeded and planted areas where slopes are steeper than 2:1 or where sensitive seedlings require insulation from extreme temperatures or moisture retention.

Siting and Design Considerations

When possible, organic mulches should be used for erosion control and plant material establishment. Suggested materials include loose straw, netting, wood cellulose, or agricultural silage. All materials should be free of seed, and loose hay or straw should be anchored by applying tackifier, stapling netting over the top, or crimping with a mulch crimping tool. Materials that are heavy enough to stay in place (for example, gravel or bark or wood chips on flat slopes) do not need anchoring. Other examples include hydraulic mulch products with 100-percent post-consumer paper content, yard trimming composts, and wood mulch from recycled stumps and tree parts. Inorganic mulches such as pea gravel or crushed granite can be used in unvegetated areas.

Mulches may or may not require a binder, netting, or tacking. Effective use of netting and matting material requires firm, continuous contact between the materials and the soil. If there is no contact, the material will not hold the soil and erosion will occur underneath the material. Grading is not necessary before mulching. There must be adequate coverage to prevent erosion, washout, and poor plant establishment. If an appropriate tacking agent is not applied, or is applied in insufficient amounts, mulch is lost to wind and runoff. The channel grade and liner must be appropriate for the amount of runoff, or there will be resulting erosion of the channel bottom. Also, hydromulch should be applied in spring, summer, or fall to prevent deterioration of mulch before plants can become established. Table 1 presents guidelines for installing mulches.

Table 1. Typical mulching materials and application rates

Material	Rate per Acre	Requirements	Notes
Organic Mulches			
Straw	1 - 2 tons	Dry, unchopped, unweathered; avoid weeds.	Spread by hand or machine; must be tacked or tied down.
Wood fiber or wood cellulose	½ - 1 ton		Use with hydroseeder; may be used to tack straw. Do not use in hot, dry weather.
Wood chips	5 - 6 tons	Air dry. Add fertilizer N, 12 lb/ton.	Apply with blower, chip handler, or by hand. Not for fine turf areas.
Bark	35 yd^3	Air dry, shredded, or hammermilled, or chips	Apply with mulch blower, chip handler, or by hand. Do not use asphalt tack.
Nets and Mats			
Jute net	Cover area	Heavy, uniform; woven of single jute yarn. Used with organic mulch.	Withstands water flow.
Excelsior (wood fiber) mat	Cover area		
Fiberglass roving	½ - 1 ton	Continuous fibers of drawn glass bound together with a non-toxic agent.	Apply with compressed air ejector. Tack with emulsified asphalt at a rate of 25 - 35 gal./1000 $ft.^2$

Limitations

Mulching, matting, and netting might delay seed germination because the cover changes soil surface temperatures. The mulches themselves are subject to erosion and may be washed away in a large storm. Maintenance is necessary to ensure that mulches provide effective erosion control.

Maintenance Considerations

Mulches must be anchored to resist wind displacement. Netting should be removed when protection is no longer needed and disposed of in a landfill or composted. Mulched areas should be inspected frequently to identify areas where mulch has loosened or been removed, especially after rainstorms. Such areas should be reseeded (if necessary) and the mulch cover replaced immediately. Mulch binders should be applied at rates recommended by the manufacturer. If washout, breakage, or erosion occurs, surfaces should be repaired, reseeded, and remulched, and new netting should be installed. Inspections should be continued until vegetation is firmly established.

Effectiveness

Mulching effectiveness varies according to the type of mulch used. Soil loss reduction for different mulches ranges from 53 to 99.8 percent. Water velocity reductions range from 24 to 78 percent. Table 2 shows soil loss and water velocity reductions for different mulch treatments.

Table 2. Measured reductions in soil loss for different mulch treatments (Source: Harding, 1990, as cited in USEPA, 1993)

Mulch Characteristics	Soil Loss Reduction (%)	Water Velocity Reduction (% relative to bare soil)
100% wheat straw/top net	97.5	73
100% wheat straw/two nets	98.6	56
70% wheat straw/30% coconut fiber	98.7	71
70% wheat straw/30% coconut fiber	99.5	78
100% coconut fiber	98.4	77
Nylon monofilament/two nets	99.8	74
Nylon monofilament/rigid/bonded	53.0	24
Vinyl monofilament/flexible/bonded	89.6	32
Curled wood fibers/top net	90.4	47
Curled wood fibers/two nets	93.5	59
Antiwash netting(jute)	91.8	59
Interwoven paper and thread	93.0	53
Uncrimped wheat straw, 2,242 kg/ha	84.0	45
Uncrimped wheat straw, 4,484 kg/ha	89.3	59

In addition, a study by Hetzog et al. (1998) concluded that mulching provides a high rate of sediment and nutrient pollution prevention. In addition, this study also found that seeding or mulching added value to a site in the eyes of the developers, real estate agents, and homebuyers that more than offset the cost of seeding or mulching.

PERMANENT SEEDING

Description

Permanent seeding is used to control runoff and erosion on disturbed areas by establishing perennial vegetative cover from seed. It is used to reduce erosion, to decrease sediment yields from disturbed areas, and to provide permanent stabilization. This practice is economical, adaptable to different site conditions, and allows selection of the most appropriate plant materials.

Applicability
Permanent seeding is well-suited in areas where permanent, long-lived vegetative cover is the most practical or most effective method of stabilizing the soil. Permanent seeding can be used on roughly graded areas that will not be regraded for at least a year. Vegetation controls erosion by protecting bare soil surfaces from displacement by raindrop impacts and by reducing the velocity and quantity of overland flow. The advantages of seeding over other means of establishing plants include lower initial costs and labor inputs.

Siting and Design Considerations
Areas to be stabilized with permanent vegetation must be seeded or planted 1 to 4 months after the final grade is achieved unless temporary stabilization measures are in place. Successful plant establishment can be maximized with proper planning; consideration of soil characteristics; selection of plant materials that are suitable for the site; adequate seedbed preparation, liming, and fertilization; timely planting; and regular maintenance. Climate, soils, and topography are major factors that dictate the suitability of plants for a particular site. The soil on a disturbed site might require amendments to provide sufficient nutrients for seed germination and seedling growth. The surface soil must be loose enough for water infiltration and root penetration. Soil pH should be between 6.0 and 6.5 and can be increased with liming if soils are too acidic. Seeds can be protected with mulch to retain moisture, regulate soil temperatures, and prevent erosion during seedling establishment.

Depending on the amount of use permanently seeded areas receive, they can be considered high- or low-maintenance areas. High-maintenance areas are mowed frequently, limed and fertilized regularly, and either (1) receive intense use (e.g., athletic fields) or (2) require maintenance to an aesthetic standard (e.g., home lawns). Grasses used for high-maintenance areas are long-lived perennials that form a tight sod and are fine-leaved. High-maintenance vegetative cover is used for homes, industrial parks, schools, churches, and recreational areas.

Low-maintenance areas are mowed infrequently or not at all and do not receive lime or fertilizer on a regular basis. Plants must be able to persist with minimal maintenance over long periods of time. Grass and legume mixtures are favored for these sites because legumes fix nitrogen from the atmosphere. Sites suitable for low-maintenance vegetation include steep slopes, stream or channel banks, some commercial properties, and "utility" turf areas such as road banks.

Limitations
The effectiveness of permanent seeding can be limited because of the high erosion potential during establishment, the need to reseed areas that fail to establish, limited seeding times depending on the season, and the need for stable soil temperature and soil moisture content during germination and early growth. Permanent seeding does not immediately stabilize soils—temporary erosion and sediment control measures should be in place to prevent off-site transport of pollutants from disturbed areas.

Maintenance Considerations
Grasses should emerge within 4–28 days and legumes 5–28 days after seeding, with legumes following grasses. A successful stand should exhibit the following:

- Vigorous dark green or bluish green seedlings, not yellow
- Uniform density, with nurse plants, legumes, and grasses well intermixed
- Green leaves—perennials should remain green throughout the summer, at least at the plant bases.

Seeded areas should be inspected for failure, and necessary repairs and reseeding should be made as soon as possible. If a stand has inadequate cover, the choice of plant materials and quantities of lime and fertilizer should be reevaluated. Depending on the condition of the stand, areas can be repaired by overseeding or reseeding after complete seedbed preparation. If timing is bad, rye grain or German millet can be overseeded to thicken the stand until a suitable time for seeding perennials. Consider seeding temporary, annual species if the season is not appropriate for permanent seeding. If vegetation fails to grow, soil should be tested to determine if low pH or nutrient imbalances are responsible.

On a typical disturbed site, full plant establishment usually requires refertilization in the second growing season. Soil tests can be used to determine if more fertilizer needs to be added. Do not fertilize cool season grasses in late May through July. Grass that looks yellow may be nitrogen deficient. Do not use nitrogen fertilizer if the stand contains more than 20 percent legumes.

Effectiveness

Perennial vegetative cover from seeding has been shown to remove between 50 and 100 percent of total suspended solids from storm water runoff, with an average removal of 90 percent (USEPA, 1993).

SODDING

Description

Sodding is a permanent erosion control practice that involves laying a continuous cover of grass sod on exposed soils. In addition to stabilizing soils, sodding can reduce the velocity of storm water runoff. Sodding can provide immediate vegetative cover for critical areas and stabilize areas that cannot be vegetated by seed. It also can stabilize channels or swales that convey concentrated flows and can reduce flow velocities.

Applicability

Sodding is appropriate for any graded or cleared area that might erode, requiring immediate vegetative cover. Locations particularly well-suited to sod stabilization are:

- Residential or commercial lawns and golf courses where prompt use and aesthetics are important
- Steeply-sloped areas
- Waterways and channels carrying intermittent flow
- Areas around drop inlets that require stabilization.

Site and Design Considerations

Sodding eliminates the need for seeding and mulching and produces more reliable results with less maintenance. Sod can be laid during times of the year when seeded grasses are likely to fail. The sod must be watered frequently within the first few weeks of installation. The type of sod selected should be composed of plants adapted to site conditions. Sod composition should reflect environmental conditions as well as the function of the area where the sod will be laid. The sod should be of known genetic origin and be free of noxious weeds, diseases, and insects. The sod should be machine cut at a uniform soil thickness of 15 to 25 mm at the time of establishment (this does not include top growth or thatch).

Soil preparation and additions of lime and fertilizer may be needed; soils should be tested to determine if amendments are needed. Sod should be laid in strips perpendicular to the direction of waterflow and staggered in a brick-like pattern. The corners and middle of each strip should be stapled firmly. Jute or plastic netting may be pegged over the sod for further protection against washout during establishment. Areas to be sodded should be cleared of trash, debris, roots, branches, stones and clods larger than 2 inches in diameter. Sod should be harvested, delivered, and installed within a period of 36 hours. Sod not transplanted within this period should be inspected and approved prior to its installation.

Limitations

Compared to seed, sod is more expensive and more difficult to obtain, transport, and store. Care must be taken to prepare the soil and provide adequate moisture before, during, and after installation to ensure successful establishment. If sod is laid on poorly prepared soil or unsuitable surface, the grass will die quickly because it is unable to root. Sod that is not adequately irrigated after installation may cause root dieback because grass does not root rapidly and is subject to drying out.

Maintenance Considerations

Watering is very important to maintain adequate moisture in the root zone and to prevent dormancy, especially within the first few weeks of installation, until it is fully rooted. Mowing should not result in the removal of more than one-third of the shoot. Grass height should be maintained between 2 and 3 inches. After the first growing season, sod might require additional fertilization or liming. Permanent, fine turf areas require yearly maintenance fertilization. Warm-season grass should be fertilized in late spring to early summer, and cool-season grass, in late winter and again in early fall.

Effectiveness

Sod has been shown to remove up to 99 percent of total suspended solids in runoff. It is therefore a highly effective management practice for erosion and sediment control, but its trapping efficiency is highly variable depending on hydrologic, hydraulic, vegetation, and sediment characteristics.

SOIL ROUGHENING

Description

Soil roughening is a temporary erosion control practice often used in conjunction with grading. Soil roughening involves increasing the relief of a bare soil surface with horizontal grooves, stair-stepping (running parallel to the contour of the land), or tracking using construction equipment. Slopes that are not fine graded and that are left in a roughened condition can also reduce erosion. Soil roughening reduces runoff velocity, increases infiltration, reduces erosion, traps sediment, and prepares the soil for seeding and planting by giving seed an opportunity to take hold and grow.

Applicability

Soil roughening is appropriate for all slopes. Soil roughening works well on slopes greater than 3:1, on piles of excavated soil, and in areas with highly erodible soils. This technique is especially appropriate for soils that are frequently mowed or disturbed because roughening is relatively easy to accomplish. To slow erosion, roughening should be done as soon as possible after the vegetation has been removed form the slope. Roughening can be used with both seeding and planting and temporary mulching to stabilize an area. For steeper slopes and slopes that will be left roughened for longer periods of time, a combination of surface roughening and vegetation is appropriate. Roughening should be performed immediately after grading activities have ceased (temporarily or permanently) in an area.

Site and Design Considerations

Rough slope surfaces are preferred because they aid the establishment of vegetation, improve infiltration, and decrease runoff velocity. Graded areas with smooth, hard surfaces might seem appropriate, but such surfaces may increase erosion potential. A rough soil surface allows surface ponding that protects lime, fertilizer, and seed. Grooves in the soil are cooler and provide more favorable moisture conditions than hard, smooth surfaces. These conditions promote seed germination and vegetative growth.

It is important to avoid excessive compacting of the soil surface, especially when tracking, because soil compaction inhibits vegetation growth and causes higher runoff velocity. Therefore, it is best to limit roughening with tracked machinery to sandy soils that do not compact easily and to avoid tracking on heavy clay soils, particularly when wet. Roughened areas should be seeded as quickly as possible. Proper dust control procedures also should be followed when soil roughening.

There are different methods for achieving a roughened soil surface on a slope. The selection of an appropriate method depends on the type of slope and the available equipment. Roughening methods include stair-step grading, grooving, and tracking. Factors to consider when choosing a method are slope steepness, mowing requirements, whether the slope is formed by cutting or filling, and available equipment. The following methods can be used for surface roughening

Cut slope roughening for areas that will not be mowed. Stair-step grades or groove-cut slopes should be used for gradients steeper than 3:1. Stair-step grading should be used on any erodible material that is soft enough to be ripped with a bulldozer. Slopes consisting of soft rock with some subsoil are particularly suited to stair-step grading. The vertical cut distance should be less than the horizontal distance, and the horizontal portion of the step should be slightly sloped toward the vertical wall. Individual vertical cuts should not be made more than 2 feet deep in soft materials or more than 3 feet deep in rocky materials.

Grooving. This technique uses machinery to create a series of ridges and depressions that run across the slope along the contour. Grooves should be made using any appropriate implement that can be safely operated on the slope, such as disks, tillers, spring harrows, or the teeth on a front-end loader bucket. The grooves should be made more than 3 inches deep and less than 15 inches apart.

Fill slope roughening for areas that will not be mowed. Fill slopes with a gradient steeper than 3:1 should be placed in lifts less than 9 inches, and each lift should be properly compacted. The face of the slope should consist of loose, uncompacted fill 4 to 6 inches deep. Grooving should be used as described above to roughen the face of the slopes, if necessary. The final slope face should not be bladed or scraped.

Cuts, fills, and graded areas that will be mowed. Mowed slopes should be made no steeper than 3:1. These areas should be roughened with shallow grooves less than 10 inches apart and more than 1 inch deep using normal tilling, disking, or harrowing equipment (a cultipacker-seeder can also be used). Excessive roughness is undesirable where mowing is planned.

Roughening with tracked machinery. Roughening with tracked machinery should be limited to sandy soils to avoid undue compaction of the soil surface. Tracked machinery should be operated perpendicular to the slope to leave horizontal depressions in the soil. Tracking is generally not as effective as other roughening methods.

Limitations

Soil roughening is not appropriate for rocky slopes. Soil compaction might occur when roughening with tracked machinery. Soil roughening is of limited effectiveness in anything more than a gentle or shallow depth rain. If roughening is washed away in a heavy storm, the surface will have to be re-roughened and new seed laid.

Maintenance Considerations

Areas need to be inspected after storms, since roughening might need to be repeated. Regular inspection of roughened slopes will indicate where additional erosion and sediment control measures are needed. If rills (small watercourses that have steep sides and are usually only a few inches deep) appear, they should be filled, graded again, and reseeded immediately. Proper dust control methods should be used.

Effectiveness

Soil roughening provides moderate erosion protection for bare soils while vegetative cover is being established. It is inexpensive and simple for short-term erosion control when used with other erosion and sediment controls.

GEOTEXTILES

Description

Geotextiles are porous fabrics also known as filter fabrics, road rugs, synthetic fabrics, construction fabrics, or simply fabrics. Geotextiles are manufactured by weaving or bonding fibers made from synthetic materials such as polypropylene, polyester, polyethylene, nylon, polyvinyl chloride, glass, and various mixtures of these materials. As a synthetic construction material, geotextiles are used for a variety of purposes such as separators, reinforcement, filtration and drainage, and erosion control (USEPA, 1992). Some geotextiles are made of biodegradable materials such as mulch matting and netting. Mulch mattings are jute or other wood fibers that have been formed into sheets and are more stable than normal mulch. Netting is typically made from jute, wood fiber, plastic, paper, or cotton and can be used to hold the mulching and matting to the ground. Netting can also be used alone to stabilize soils while the plants are growing; however, it does not retain moisture or temperature well. Mulch binders (either asphalt or synthetic) are sometimes used instead of netting to hold loose mulches together. Geotextiles can aid in plant growth by holding seeds, fertilizers, and topsoil in place. Fabrics are relatively inexpensive for certain applications. A wide variety of geotextiles exist to match the specific needs of the site.

Applicability

Geotextiles can be used alone for erosion control. Geotextiles can be used as matting, which is used to stabilize the flow of channels or swales or to protect seedlings on recently planted slopes until they become established. Matting may be used on tidal or stream banks, where moving water is likely to wash out new plantings. They can also be used to protect exposed soils immediately and temporarily, such as when active piles of soil are left overnight. Geotextiles are also used as separators; for example, as a separator between riprap and soil. This "sandwiching" prevents the soil from being eroded from beneath the riprap and maintains the riprap's base.

Siting and Design Considerations

There are many types of geotextiles available. Therefore, the selected fabric should match its purpose. State or local requirements, design procedures, and any other applicable requirements should be considered. Effective netting and matting require firm, continuous contact between the materials and the soil. If there is no contact, the material will not hold the soil, and erosion will occur underneath the material.

Limitations
Geotextiles (primarily synthetic types) have the potential disadvantage of being sensitive to light and must be protected prior to installation. Some geotextiles might promote increased runoff and might blow away if not firmly anchored. Depending on the type of material used, geotextiles might need to be disposed of in a landfill, making them less desirable than vegetative stabilization. If the fabric is not properly selected, designed, or installed, the effectiveness may be reduced drastically.
Maintenance Considerations
Regular inspections should be made to determine if cracks, tears, or breaches have formed in the fabric; if so, it should be repaired or replaced immediately. It is necessary to maintain contact between the ground and the geotextile at all times. Trapped sediment should be removed after each storm event.
Effectiveness
Geotextiles' effectiveness depends upon the strength of the fabric and proper installation. For example, when protecting a cut slope with a geotextile, it is important to properly anchor the fabric. This will ensure that it will not be undermined by a storm event.

SOIL RETENTION

Description
Soil retention measures are structures or practices that are used to hold soil in place or to keep it contained within a site boundary. They may include grading or reshaping the ground to lessen steep slopes or shoring excavated areas with wood, concrete, or steel structures. Some soil-retaining measures are used for erosion control, while others are used for protection of workers during construction projects such as excavations.
Applicability
Grading to reduce steep slopes can be implemented at any construction site by assessing site conditions before breaking ground and reducing steep slopes where possible. Reinforced soil-retaining structures should be used when sites have very steep slopes or loose, highly erodible soils that cause other methods, such as chemical or vegetative stabilization or regrading, to be ineffective. The preconstruction drainage pattern should be maintained to the extent possible.
Site and Design Considerations
Some examples of reinforced soil retaining structures include:

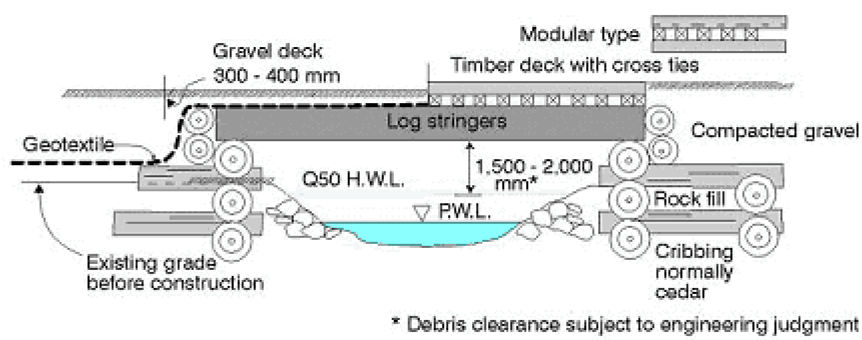
- *Skeleton sheeting*. An inexpensive soil bracing system that requires soil to be cohesive and consists of construction grade lumber being used to support the excavated face of a slope
- *Continuous sheeting*. Involves using a material that covers the entire slope continuously, with struts and boards placed along the slope to support the slope face - steel, concrete, or wood should be used as the materials
- *Permanent retaining walls*. Walls of concrete masonry or wood (railroad ties) that are left in place after construction is complete in order to provide continued support of the slope

The proper design of reinforced soil-retaining structures is crucial for erosion control and safety. To ensure safety of the retaining structure, it should be designed by a qualified engineer who understands all of the design considerations, such as the nature of the soil, location of the ground water table, and the expected loads. Care should be taken to ensure that hydraulic pressure does not build up behind the retaining structure and cause failure.

Limitations
To be effective, soil-retention structures must be designed to handle expected loads. However, heavy rains or mass wasting may damage or destroy these structures and result in sediment inputs to waterbodies. They must be properly installed and maintained to avoid failure.
Maintenance Considerations
Soil-stabilization structures should be inspected periodically, particularly after rainstorms, to check for erosion, damage, or other signs of deterioration. Any damage to the actual slope or ditch, such as washouts or breakage, should be repaired prior to any reinstallation of the materials for the soil-stabilization structure.

Effectiveness
Soil-retention structures, if properly designed and installed, can effectively prevent erosion and mass wasting in areas with steep slopes and erodible soils. Their potential for failure depends on their design, installation, maintenance, and the likelihood of catastrophic events such as heavy rains, earthquakes, and landslides.

Temporary Stream Crossings
Description
A temporary steam crossing is a structure erected to provide a safe and stable way for construction vehicle traffic to cross a running watercourse. The primary purpose of such a structure is to provide streambank stabilization, reduce the risk of damaging the streambed or channel, and reduce the risk of sediment loading from construction traffic. A temporary stream crossing may be a bridge, a culvert, or a ford.
Applicability
Temporary stream crossings are applicable wherever heavy construction equipment must be moved from one side of a stream channel to the other, or where lighter construction vehicles will cross the stream a number of times during the construction period. In either case, an appropriate method for ensuring the stability of the streambanks and preventing large-scale erosion is necessary.
A bridge or culvert is the best choice for most temporary stream crossings. If properly designed, each can support heavy loads and materials used to construct most bridges, and culverts can be salvaged after they are removed. Fords are appropriate in steep areas subject to flash flooding, where normal flow is shallow or intermittent across a wide channel. Fords should be used only where stream crossings are expected to be infrequent.
Site and Design Considerations
Because of the potential for stream degradation, flooding, and safety hazards, stream crossings should be avoided on a construction site whenever possible. Consideration should be given to alternative routes to accessing a site before arrangements are made to erect a temporary stream crossing. If it is determined that a stream crossing is necessary, an area where the potential for erosion is low should be selected. If possible, the stream crossing structure should be selected during a dry period to reduce sediment transport into the stream. If needed, over-stream bridges are generally the preferred temporary stream crossing structure. The expected load and frequency of the stream crossing, however, will govern the selection of a bridge as the correct choice for a temporary stream crossing. Bridges usually cause minimal disturbance to a stream's banks and cause the least obstruction to stream flow and fish migration. They should be constructed only under the supervision and approval of a qualified engineer.



Properly installed stream crossings can prevent destruction of stream habitat (Source: British Columbia Ministry of Forests, no date)

As general guidelines for constructing temporary bridges, clearing and excavation of the stream shores and bed should be kept to a minimum. Sufficient clearance should be provided for floating objects to pass under the bridge. Abutments should be parallel to the stream and on stable banks. If the stream is less than 8 feet wide at the point a crossing is needed, no additional in-stream supports should be used. If the crossing is to extend across a channel wider than 8 feet (as measured from top of bank to top of bank), the bridge should be designed with one in-water support for each 8 feet of stream width.

A temporary bridge should be anchored by steel cable or chain on one side only to a stable structure on shore. Examples of anchoring structures include large-diameter trees, large boulders, and steel anchors. By anchoring the bridge on one side only, there is a decreased risk of downstream blockage or flow diversion if a bridge is washed out.

When constructing a culvert, filter cloth should be used to cover the streambed and streambanks to reduce settlement and improve the stability of the culvert structure. The filter cloth should extend a minimum of 6 inches and a maximum of 1 foot beyond the end of the culvert and bedding material. The culvert piping should not exceed 40 feet in length and should be of sufficient diameter to allow for complete passage of flow during peak flow periods. The culvert pipes should be covered with a minimum of 1 foot of aggregate. If multiple culverts are used, at least 1 foot of aggregate should separate the pipes.

Fords should be constructed of stabilizing material such as large rocks.

Limitations

Bridges can be considered the greatest safety hazard of all temporary stream crossing structures if not properly designed and constructed. Bridges might also prove to be more costly in terms of repair costs and lost construction time if they are washed out or collapse (Smolen et al., 1988).

The construction and removal of culverts are usually very disturbing to the surrounding area, and erosion and downstream movement of soils is often great. Culverts can also create obstructions to flow in a stream and inhibit fish migration. Depending on their size, culverts can be blocked by large debris in a stream and are therefore vulnerable to frequent washout.

If given a choice between building a bridge or a culvert as a temporary stream crossing, a bridge is preferred because of the relative minimal disturbance to streambanks and the opportunity for unimpeded flow through the channel.

The approaches to fords often have high erosion potential. In addition, excavation of the streambed and approach to lay riprap or other stabilization material causes major stream disturbance. Mud and other debris are transported directly into the stream unless the crossing is used only during periods of low flow.

Maintenance Considerations

Temporary stream crossings should be inspected at least once a week and after all significant rainfall events. If any structural damage is reported to a bridge or culvert, construction traffic should stop use of the structure until appropriate repairs are made. Evidence of streambank erosion should be repaired immediately.

Fords should be inspected closely after major storm events to ensure that stabilization materials remain in place. If the material has moved downstream during periods of peak flow, the lost material should be replaced immediately.

Effectiveness

Both temporary bridges and culverts provide an adequate path for construction traffic crossing a stream or watercourse.

VEGETATED BUFFER

Description

Vegetated buffers are areas of either natural or established vegetation that are maintained to protect the water quality of neighboring areas. Buffer zones reduce the velocity of storm water runoff, provide an area for the runoff to permeate the soil, contribute to ground water recharge, and act as filters to catch sediment. The reduction in velocity also helps to prevent soil erosion.

Applicability

Vegetated buffers can be used in any area that is able to support vegetation but they are most effective and beneficial on floodplains, near wetlands, along streambanks, and on steep, unstable slopes. They are also effective in separating land use areas that are not compatible and in protecting wetlands or waterbodies by displacing activities that might be potential sources of nonpoint source pollution.

Site and Design Considerations

To establish an effective vegetative buffer, the following guidelines should be followed:

- Soils should not be compacted.

- Slopes should be less than 5 percent.
- Buffer widths should be determined after careful consideration of slope, vegetation, soils, depth to impermeable layers, runoff sediment characteristics, type and quantity of storm water pollutants, and annual rainfall.
- Buffer widths should increase as slope increases.
- Zones of vegetation (native vegetation in particular), including grasses, deciduous and evergreen shrubs, and understory and overstory trees, should be intermixed.
- In areas where flows are concentrated and velocities are high, buffer zones should be combined with other structural or nonstructural BMPs as a pretreatment.

Limitations

Vegetated buffers require plant growth before they can be effective, and land on which to plant the vegetation must be available. If the cost of the land is very high, buffer zones might not be cost-effective. Although vegetated buffers help to protect water quality, they usually do not effectively counteract concentrated storm water flows to neighboring or downstream wetlands.

Maintenance Considerations

Keeping vegetation healthy in vegetated buffers requires routine maintenance, which (depending on species, soil types, and climatic conditions) can include weed and pest control, mowing, fertilizing, liming, irrigating, and pruning. Inspection and maintenance are most important when buffer areas are first installed. Once established, vegetated buffers do not require much maintenance beyond the routine procedures listed earlier and periodic inspections of the areas, especially after any heavy rainfall and at least once a year. Inspections should focus on encroachment, gully erosion, density of vegetation, evidence of concentrated flows through the areas, and any damage from foot or vehicular traffic. If there is more than 6 inches of sediment in one place, it should be removed.

Effectiveness

Several researchers have measured greater than 90 percent reductions in sediment and nitrate concentrations. Buffer/filter strips do a reasonably good job of removing phosphorus attached to sediment, but are relatively ineffective in removing dissolved phosphorus (Gilliam, 1994).

CONSTRUCTION SEQUENCING

Description

Construction sequencing requires creating and following a work schedule that balances the timing of land disturbance activities and the installation of measures to control erosion and sedimentation, in order to reduce on-site erosion and off-site sedimentation.

Applicability

Construction sequencing can be used to plan earthwork and erosion and sediment control (ESC) activities at sites where land disturbances might affect water quality in a receiving waterbody.

Site and Design Considerations

Construction sequencing schedules should, at a minimum, include the following:

- The ESC practices that are to be installed
- Principal development activities
    - Which measures should be installed before other activities are started
    - Compatibility with the general contract construction schedule

Table 1 summarizes other important scheduling considerations in addition to those listed above.
Table 1. Scheduling considerations for construction activities.

Construction Activity	Schedule Consideration
Construction access—entrance to site, construction routes, areas designated for equipment parking	This is the first land-disturbing activity. As soon as construction begins, stabilize any bare areas with gravel and temporary vegetation.
Sediment traps and barriers—basin traps, sediment fences, outlet protection	After construction site is accessed, principal basins should be installed, with the addition of more traps and barriers as needed during grading.
Runoff control—diversions, perimeter dikes, water bars, outlet protection	Key practices should be installed after the installation of principal sediment traps and before land grading. Additional runoff control measures may be installed during grading.
Runoff conveyance system—stabilize stream banks, storm drains, channels, inlet and outlet protection, slope drains	If necessary, stabilize stream banks as soon as possible, and install principal runoff conveyance system with runoff control measures. The remainder of the systems may be installed after grading.
Land clearing and grading—site preparation (cutting, filling, and grading, sediment traps, barriers, diversions, drains, surface roughening)	Implement major clearing and grading after installation of principal sediment and key runoff-control measures, and install additional control measures as grading continues. Clear borrow and disposal areas as needed, and mark trees and buffer areas for preservation.
Surface stabilization—temporary and permanent seeding, mulching, sodding, riprap	Temporary or permanent stabilizing measures should be applied immediately to any disturbed areas where work has been either completed or delayed.
Building construction—buildings, utilities, paving	During construction, install any erosion and sedimentation control measures that are needed.
Landscaping and final stabilization—topsoiling, trees and shrubs, permanent seeding, mulching, sodding, riprap	This is the last construction phase. Stabilize all open areas, including borrow and spoil areas, and remove and stabilize all temporary control measures.

Limitations
Weather and other unpredictable variables may affect construction sequence schedules. However, the proposed schedule and a protocol for making changes due to unforeseen problems should be plainly stated in the ESC plan.
Maintenance Considerations
The construction sequence should be followed throughout the project and the written plan should be modified before any changes in construction activities are executed. The plan can be updated if a site inspection indicates the need for additional erosion and sediment control.
Effectiveness
Construction sequencing can be an effective tool for erosion and sediment control because it ensures that management practices are installed where necessary and when appropriate. The plan must be followed and updated if needed to maximize the effectiveness of ESC under changing conditions.

DUST CONTROL
Description
Dust control measures are practices that help reduce surface and air movement of dust from disturbed soil surfaces. Construction sites are good candidates for dust control measures because land disturbance from clearing and excavation generates a large amount of soil disturbance and open space for wind to pick up dust particles. To illustrate this point, limited research at construction sites has established an average dust emission rate of 1.2 tons/acre/month for active construction (WA Dept. of Ecology, 1992). These airborne particles pose a dual threat to the environment and human health. First, dust can be carried off-site, thereby

increasing soil loss from the construction area and increasing the likelihood of sedimentation and water pollution. Second, blowing dust particles can contribute to respiratory health problems and create an inhospitable working environment.

Applicability

Dust control measures are applicable to any construction site where dust is created and there is the potential for air and water pollution from dust traveling across the landscape or through the air. Dust control measures are particularly important in arid or semiarid regions, where soil can become extremely dry and vulnerable to transport by high winds. Also, dust control measures should be implemented on all construction sites where there will be major soil disturbances or heavy construction activity, such as clearing, excavation, demolition, or excessive vehicle traffic. Earthmoving activities are the major source of dust from construction sites, but traffic and general disturbances can also be major contributors (WA Dept. of Ecology, 1992). The particular dust control measures that are implemented at a site will depend on the topography and land cover of a given site, as well as the soil characteristics and expected rainfall at the site.

Site and Design Considerations

When designing a dust control plan for a site, the amount of soil exposed will dictate the quantity of dust generation and transport. Therefore, construction sequencing and disturbing only small areas at a time can greatly reduce problematic dust from a site. If land must be disturbed, additional temporary stabilization measures should be considered prior to disturbance. A number of methods can be used to control dust from a site. The following is a brief list of some control measures and their design criteria. Not all control measures will be applicable to a given site. The owner, operator, and contractors responsible for dust control at a site will have to determine which practices accommodate their needs based on specific site and weather conditions.

- *Sprinkling/Irrigation*. Sprinkling the ground surface with water until it is moist is an effective dust control method for haul roads and other traffic routes (Smolen et al., 1988). This practice can be applied to almost any site.
- *Vegetative Cover*. In areas not expected to handle vehicle traffic, vegetative stabilization of disturbed soil is often desirable. Vegetative cover provides coverage to surface soils and slows wind velocity at the ground surface, thus reducing the potential for dust to become airborne.
- *Mulch*. Mulching can be a quick and effective means of dust control for a recently disturbed area (Smolen et al., 1988).
- *Wind Breaks*. Wind breaks are barriers (either natural or constructed) that reduce wind velocity through a site and therefore reduce the possibility of suspended particles. Wind breaks can be trees or shrubs left in place during site clearing or constructed barriers such as a wind fence, snow fence, tarp curtain, hay bale, crate wall, or sediment wall (USEPA, 1992).
- *Tillage*. Deep tillage in large open areas brings soil clods to the surface where they rest on top of dust, preventing it from becoming airborne.
- *Stone*. Stone may be an effective dust deterrent for construction roads and entrances or as a mulch in areas where vegetation cannot be established.
- *Spray-on Chemical Soil Treatments (palliatives)*. Examples of chemical adhesives include anionic asphalt emulsion, latex emulsion, resin-water emulsions, and calcium chloride. Chemical palliatives should be used only on mineral soils. When considering chemical application to suppress dust, consideration should be taken as to whether the chemical is biodegradable or water-soluble and what effect its application could have on the surrounding environment, including waterbodies and wildlife.

Table 1 shows application rates for some common spray-on adhesives, as recommended by Smolen et al. (1988).

Table 1. Application rates for spray-on adhesives (Source: Smolen et al., 1988)

Spray-on Adhesive	**Water Dilution**	**Type of Nozzle**	**Application (gal/ac)**
Anionic Asphalt Emulsion	7:1	Coarse Spray	1,200
Latex Emulsion	12.5:1	Fine Spray	235
Resin in Water	4:1	Fine Spray	300

Limitations
In areas where evaporation rates are high, water application to exposed soils may require near constant attention. If water is applied in excess, irrigation may create unwanted excess runoff from the site and possibly create conditions where vehicles could track mud onto public roads. Chemical applications should be used sparingly and only on mineral soils (not muck soils) because their misuse can create additional surface water pollution from runoff or contaminate ground water. Chemical applications might also present a health risk if excessive amounts are used.
Maintenance Considerations
Because dust controls are dependent on specific site and weather conditions, inspection and maintenance are unique for each site. Generally, however, dust control measures involving application of either water or chemicals require more monitoring than structural or vegetative controls to remain effective. If structural controls are used, they should be inspected for deterioration on a regular basis to ensure that they are still achieving their intended purpose.
Effectiveness

- *Sprinkling/Irrigation*. Not available.
- *Vegetative Cover*. Not available.
- *Mulch*. Can reduce wind erosion by up to 80 percent.
- *Wind Breaks/Barriers*. For each foot of vertical height, an 8-to 10-foot deposition zone develops on the leeward side of the barrier. The permeability of the barrier will change its effectiveness at capturing windborne sediment.
- *Tillage*. Roughening the soil can reduce soil losses by approximately 80 percent in some situations.
- *Stone*. The sizes of the stone can affect the amount of erosion to take place. In areas of high wind, small stones are not as effective as 20 cm stones.
- *Spray-on Chemical Soil Treatments (palliatives)*. Effectiveness of polymer stabilization methods range from 70 percent to 90 percent, according to limited research.

SILT FENCE
Description
Silt fences are used as temporary perimeter controls around sites where there will be soil disturbance due to construction activities. They consist of a length of filter fabric stretched between anchoring posts spaced at regular intervals along the site perimeter. The filter fabric should be entrenched in the ground between the support posts. When installed correctly and inspected frequently, silt fences can be an effective barrier to sediment leaving the site in storm water runoff.
Applicability
Silt fences are generally applicable to construction sites with relatively small drainage areas. They are appropriate in areas where runoff will be occurring as low-level shallow flow, not exceeding 0.5 cfs. The drainage area for silt fences generally should not exceed 0.25 acre per 100-foot fence length. Slope length above the fence should not exceed 100 feet (NAHB, 1995).
Site and Design Considerations
Material for silt fences should be a pervious sheet of synthetic fabric such as polypropylene, nylon, polyester, or polyethylene yarn, chosen based on minimum synthetic fabric requirements, as shown in Table 1.

Table 1. Minimum requirements for silt fence construction (Sources: USEPA, 1992; VDCR, 1995)

Physical Property	Requirements
Filtering Efficiency	75 - 85% (minimum): highly dependent on local conditions
Tensile Strength at 20% (maximum) Elongation	Standard Strength: 30 lbs/linear inch (minimum) Extra Strength: 50 lbs/linear inch (minimum)
Ultraviolet Radiation	90% (minimum)
Slurry Flow Rate	0.3 gal/ft2/min (minimum)

If a standard strength fabric is used, it can be reinforced with wire mesh behind the filter fabric. This can increase the effective life of the fence. In any case, the maximum life expectancy for synthetic fabric silt fences is approximately 6 months, depending on the amount of rainfall and runoff for a given area. Burlap fences have a much shorter useful life span, usually only up to 2 months.

Stakes used to anchor the filter fabric should be either wooden or metal. Wooden stakes should be at least 5 feet long and have a minimum diameter of 2 inches if a hardwood such as oak is used. Softer woods such as pine should be at least 4 inches in diameter. When using metal post in place of wooden stakes, they should have a minimum weight of 1.00 to 1.33 lb/linear foot. If metal posts are used, attachment points are needed for fastening the filter fabric using wire ties.

A silt fence should be erected in a continuous fashion from a single roll of fabric to eliminate unwanted gaps in the fence. If a continuous roll of fabric is not available, the fabric should overlap from both directions only at stakes or posts with a minimum overlap of 6 inches. A trench should be excavated to bury the bottom of the fabric fence at least 6 inches below the ground surface. This will help prevent gaps from forming near the ground surface that would render the fencing useless as a sediment barrier.

The height of the fence posts should be between 16 and 34 inches above the original ground surface. If standard strength fabric is used in combination with wire mesh, the posts should be spaced no more than 10 feet apart. If extra-strength fabric is used without wire mesh reinforcement, the support posts should be spaced no more than 6 feet apart (VDCR, 1995).

The fence should be designed to withstand the runoff from a 10-year peak storm event, and once installed should remain in place until all areas up-slope have been permanently stabilized by vegetation or other means.

Limitations

Silt fences should not be installed along areas where rocks or other hard surfaces will prevent uniform anchoring of fence posts and entrenching of the filter fabric. This will greatly reduce the effectiveness of silt fencing and can create runoff channels leading off site. Silt fences are not suitable for areas where large amounts of concentrated runoff are likely. In addition, open areas where wind velocity is high may present a maintenance challenge, as high winds may accelerate deterioration of the filter fabric. Silt fences should not be installed across streams, ditches, or waterways (Smolen et al., 1988).

When the pores of the fence fabric become clogged with sediment, pools of water are likely to form on the uphill side of fence. Siting and design of the silt fence should account for this and care should be taken to avoid unnecessary diversion of storm water from these pools that might cause further erosion damage.

Maintenance Considerations

Silt fences should be inspected regularly and frequently as well as after each rainfall event to ensure that they are intact and that there are no gaps at the fence-ground interface or tears along the length of the fence. If gaps or tears are found, they should be repaired or the fabric should be replaced immediately. Accumulated sediments should be removed from the fence base when the sediment reaches one-third to one-half the height of the fence. Sediment removal should occur more frequently if accumulated sediment is creating noticeable strain on the fabric and there is the possibility of the fence failing from a sudden storm event. When the silt fence is removed, the accumulated sediment also should be removed.

Effectiveness
USEPA (1993) reports the following effectiveness ranges for silt fences constructed of filter fabric that are properly installed and well maintained: average total suspended solids removal of 70 percent, sand removal of 80 to 90 percent, silt-loam removal of 50 to 80 percent, and silt-clay-loam removal of 0 to 20 percent. Removal rates are highly dependent on local conditions and installation.

SEDIMENT BASINS AND ROCK DAMS

Description
Sediment basins and rock dams are two ways to capture sediment from storm water runoff before it leaves a construction site. Both structures allow a shallow pool to form in an excavated or natural depression where sediment from storm water runoff can settle. Basin dewatering is achieved either through a single riser and drainage hole leading to a suitable outlet on the downstream side of the embankment or through the gravel of the rock dam. In both cases, water is released at a substantially slower rate than would be possible without the control structure.

A sediment basin can be constructed by excavation or by erecting an earthen embankment across a low area or drainage swale. The basin can be either a temporary (up to 3 years) structure or a permanent storm water control measure. Sediment basins can be designed to drain completely during dry periods, or they can be constructed so that a shallow, permanent pool of water remains between storm events. However, depending on the size of the basin constructed, the basin may be considered a wet pond and subject to additional regulation.

Rock dams are similar in design to sediment basins with earthen embankments. These damming structures are constructed of rock and gravel and release water from the settling pool gradually through the spaces between the rock aggregate.

Applicability
Sediment basins are usually used for drainage areas of 5 to 100 acres. They can be temporary or permanent structures. Generally, sediment basins designed to be used for up to 3 years are described as temporary, while those designed for longer service are said to be permanent. Temporary sediment basins can be converted into permanent storm water runoff management ponds, but they must meet all regulatory requirements for wet ponds.

Sediment basins are applicable in drainage areas where it is anticipated that other erosion controls, such as sediment traps, will not be sufficient to prevent off-site transport of sediment. Choosing to construct a sediment basin with either an earthen embankment or a stone/rock dam will depend on the materials available, location of the basin, and desired capacity for storm water runoff and settling of sediments.

Rock dams are suitable where earthen embankments would be difficult to construct or where riprap is readily available. Rock structures are also desirable where the top of the dam structure is to be used as an overflow outlet. These riprap dams are best for drainage areas of less than 50 acres. Earthen damming structures are appropriate where failure of the dam will not result in substantial damage or loss of property or life. If properly constructed, sediment basins with earthen dams can handle storm water runoff from drainage basins as large as 100 acres.

Siting and Design Considerations
The potential sites for sediment basins should be investigated during the initial site evaluation. Basins should be constructed before any grading takes place within the drainage area. For structures that will be permanent, the design of the basin should be completed by a qualified professional engineer experienced in the design of dams.

Sediment basins with rock dams should be limited to a drainage area of 50 acres. Rock dam height should be limited to 8 feet with a minimum top width of 5 feet. Side slopes for rock dams should be no steeper than 2:1 on the basin side of the structure and 3:1 on the outlet side. The basin side of the rock dam should be covered with fine gravel from top to bottom for a minimum of 1 foot. This will slow the drainage rate from the pool that forms and allow time for sediments to settle. The detention time should be at least 8 hours.

Sediment basins with earthen embankments should be outfitted with a dewatering pipe and riser set just above the sediment removal cutoff level. The riser pipe should be located at the deepest point of the basin and extend no farther than 1 foot below the level of the earthen dam. A water-permeable cover should be placed over the primary dewatering riser pipe to prevent trash and debris from entering and clogging the spillway. To provide an additional path for water to enter the primary spillway, secondary dewatering holes can be drilled near the base of the riser pipe, provided the holes are protected with gravel to prevent sediment from entering the spillway piping.

To ensure adequate drainage, the following equation can be used to approximate the total area of dewatering holes for a particular basin (Smolen et al., 1988):

$$A_o = (A_s \text{ x } (2h) / (T \text{ x } C_d \text{ x } 20{,}428)$$

where

A_o = total surface area of dewatering holes, ft^2;

A_s = surface area of the basin, ft^2;

h = head of water above the hole, ft;

C_d = coefficient of contraction for an orifice, approximately 0.6; and

T = detention time or time needed to dewater the basin, hours.

In all cases, such structures should be designed by an appropriate professional based on local hydrologic, hydraulic, topographic, and sediment conditions.

Limitations

Neither a sediment basin with an earthen embankment nor a rock dam should be used in areas of continuously running water (live streams). The use of sediment basins is not intended for areas where failure of the earthen or rock dam will result in loss of life, or damage to homes or other buildings. In addition, sediment basins should not be used in areas where failure will prevent the use of public roads or utilities.

Maintenance Considerations

Routine inspection and maintenance of sediment basins is essential to their continued effectiveness. Basins should be inspected after each storm event to ensure proper drainage from the collection pool to determine the need for structural repairs. Erosion from the earthen embankment or stones moved from rock dams should be replaced immediately. Sediment basins must be located in an area that is easily accessible to maintenance crews for removal of accumulated sediment. Sediment should be removed from the basin when its storage capacity has reached approximately 50 percent. Trash and debris from around dewatering devices should be removed promptly after rainfall events.

Effectiveness

The effectiveness of a sediment basin depends primarily on the sediment particle size and the ratio of basin surface area to inflow rate (Smolen et al., 1988). Basins with a large surface area-to-volume ratio will be most effective. Studies have shown that the following equation relating surface area and peak inflow rate gives a trapping efficiency greater than 75 percent for most sediment in the Coastal Plain and Piedmont regions of the Southeastern United States (Barfield and Clar, in Smolen et al., 1988):

$$A = 0.01q$$

where A is the basin surface area in acres and q is the peak inflow rate in cubic feet per second.

USEPA (1993) estimates an average total suspended solids (TSS) removal rate for all sediment basins from 55 percent to 100 percent, with an average effectiveness of 70 percent.

SEDIMENT FILTERS AND SEDIMENT CHAMBERS

Description

Sediment filters are a class of sediment-trapping devices typically used to remove pollutants, primarily particulates, from storm water runoff. Generally speaking, sediment filters have four basic components: (1) inflow regulation, (2) pretreatment, (3) filter bed, and (4) outflow mechanism. Sediment chambers are merely one component of a sediment filter system.

Inflow regulation refers to the diversion of storm water runoff into the sediment-trapping device. After runoff enters the filter system, it enters a pretreatment sedimentation chamber. This chamber, used as a preliminary settling area for large debris and sediments, usually consists of nothing more than a wet detention basin. As water reaches a predetermined level, it flows over a weir into a filter bed of some filter medium. The filter medium is typically sand, but it can consist of sand, soil, gravel, peat, compost, or a combination of these materials. The purpose of the filter bed is to remove smaller sediments and other pollutants from the storm water as it percolates through the filter medium. Finally, treated flow exits the sediment filter system via an outflow mechanism to return to the storm water conveyance system.

Sediment filter systems can be confined or unconfined, on-line or off-line, and aboveground or belowground. Confined sediment filters are constructed with the filter medium contained in a structure, often a concrete vault. Unconfined sediment filters are constructed without encasing the filter medium in a confining structure. As one example, sand might be placed on the banks of a permanent wet pond detention system to create an unconfined filter. On-line systems are designed to retain storm water in its original stream channel or storm drain system. Off-line systems are designed to divert storm water.

Applicability

Sediment filters may be a good alternative for smaller construction sites where the use of a wet pond is being considered as a sediment-trapping device. Their applicability is wide ranging, and they can be used in urban areas with large amounts of highly impervious area. Because confined sand filters are man-made soil systems, they can be applied to most development sites and have few constraining factors (MWCOG, 1992). However, for all sediment filter systems, the drainage area to be serviced should be no more than 10 acres. The type of filter system chosen depends on the amount of land available and the desired location within the site. Examples of sediment filter systems include the "Delaware" sand filter and the "Austin" sand filter. The Austin sand filter, so named because it first came into widespread use in Austin, Texas, is a surface filter system that can be used in areas with space restrictions. If space is at a premium, an underground filter may be the most appropriate choice. For effective storm water sediment control at the perimeter of a site, the Delaware sand filter might be a good choice. This configuration consists of two parallel, trench-like chambers installed at a site's perimeter. The first trench (sediment chamber) provides pretreatment sediment settling before the runoff spills into the second trench (filter medium).

Siting and Design Considerations

Available space is likely to be the most important siting and design consideration when choosing an appropriate sediment-filtering system. As mentioned previously, the decision as to which configuration is implemented on a particular site is dependent on the amount of space on a site. Another important consideration when deciding to install sediment-filtering systems is the amount of available head. Head refers to the vertical distance available between the inflow of the filter system and the outflow point. Because most filtering systems depend on gravity as the driving force to move water through the system, if a certain amount of head is not available, the system will not be effective and might cause more harm than good. For surface and underground sand filters, a minimum head of 5 feet is suggested (Claytor and Schueler, 1996). Perimeter sand filters such as the two-chambered Delaware sand filter should have a minimum available head of 2 to 3 feet (Claytor and Schueler, 1996).

The depth of filter media will vary depending on media type, but for sand filters it is recommended that the sand (0.04-inch diameter or smaller) be at least 18 inches deep, with a minimum of 4 to 6 inches of gravel for the bed of the filter. Throughout the life of a sediment filter system, there will be a need for frequent access to assess continued effectiveness and perform routine maintenance and emergency repairs. Because most maintenance of sediment filters requires manual rather than mechanical removal of sediments and debris, filter systems should be located to allow easy access.

Limitations

Sediment filters are usually limited to the removal of pollutants from storm water runoff. They must be used in combination with other storm water management practices to provide flood protection. Sediment filters should not be used on fill sites or near steep slopes (Livingston, 1997). In addition, sediment filters are likely to lose effectiveness in cold regions because of freezing conditions.

Maintenance Considerations
Maintenance of storm water sediment filters can be relatively high compared to other sediment-trapping devices. Routine maintenance includes raking the filter medium and removal of surface sediment and trash. These maintenance chores will likely need to be accomplished by manual labor rather than mechanical means. Depending on the medium used in the structure, the filter material may have to be changed or replaced up to several times a year. This will depend, among other things, on rainfall intensity and the expected sediment load.
Sediment filters of all media types should be inspected monthly and after each significant rainfall event to ensure proper filtration. Trash and debris removal should be removed during inspections. Sediment should be removed from filter inlets and sediment chambers when 75 percent of the storage volume has been filled. Because filter media have the potential for high loadings of metals and petroleum hydrocarbons, the filter medium should be periodically analyzed to prevent it from reaching levels that would classify it as a hazardous waste. This is especially true on sites where solvents or other potentially hazardous chemicals will be used. Spill prevention measures should be implemented as necessary. The top 3 to 4 inches of the filter medium should be replaced on an annual basis, or more frequently if drawdown does not occur within 36 hours of a storm event.
Effectiveness
Treatment effectiveness will depend on a number of factors, including treatment volume; whether the filter is on-line or off-line, confined or unconfined; and the type of land use in the contributing drainage area. MWCOG (1992) state that sand filter removal rates are "high" for sediment and trace metals and "moderate" for nutrients, BOD, and fecal coliform. Removal rates can be increased slightly by using a peat/sand mixture as the filter medium due to the adsorptive properties of peat (MWCOG, 1992). Estimated pollutant removal capabilities for various storm water sediment filter systems is shown in Table 1.
Table 1. Pollutant removal efficiencies for sand filters.

Source	Filter System	TSS[a] (%)	TP[a] (%)	TN[a] (%)	Other Pollutants
Claytor and Schueler, 1996	Surface Sand Filter	85	55	35	Bacteria: 40-80% Metals: 35-90%
	Perimeter Sand Filter	80	65	45	Hydrocarbons: 80%
Livingston, 1997	Sand Filter (general)	60–85	30–75	30–60	Metals: 30–80%

[a]TSS=total suspended solids; TP=total phosphorus; TN=total nitrogen
Description
Sediment traps are small impoundments that allow sediment to settle out of runoff water. They are usually installed in a drainageway or other point of discharge from a disturbed area. Temporary diversions can be used to direct runoff to the sediment trap (USEPA, 1993). Sediment traps are used to detain sediments in storm water runoff and trap the sediment to protect receiving streams, lakes, drainage systems, and the surrounding area.
Sediment traps are formed by excavating an area or by placing an earthen embankment across a low area or drainage swale. An outlet or spillway is often constructed using large stones or aggregate to slow the release of runoff (USEPA, 1992).
Applicability
Sediment traps are generally temporary control measures to slow concentrated runoff velocity and catch sediment, and they can be used with other temporary storm water control measures. They are commonly used at the outlets of storm water diversion structures, channels, slope drains, construction site entrance wash racks, or any other runoff conveyance that discharges waters containing erosion sediment and debris.

Sediment traps can also be used as part of a storm water drop intake protection system when the inlet is located below a disturbed area and will receive runoff with large amounts of sediment.

Siting and Design Considerations

Sediment traps can simplify the storm water control plan design process by trapping sediment at specific spots at a construction site (USEPA, 1992). Therefore, they should be installed as early in the construction process as possible. Natural drainage patterns should be noted, and sites where runoff from potential erosion can be directed into the traps should be selected. Sediment traps should not be located in areas where their failure due to storm water runoff excess can lead to further erosive damage of the landscape. Alternative diversion pathways should be designed to accommodate these potential overflows.

A sediment trap should be designed to maximize surface area for infiltration and sediment settling. This will increase the effectiveness of the trap and decrease the likelihood of backup during and after periods of high runoff intensity. Although site conditions will dictate specific design criteria, the approximate storage capacity of each trap should be at least 1,800 ft^3 per acre of total drainage area (Smolen et al., 1988). The volume of a natural sedimentation trap can be approximated by the following equation (Smolen et al., 1988):

$$\text{Volume } (ft^3) = 0.4 \text{ x surface area } (ft^2) \text{ x maximum pool depth (ft)}$$

Care should be taken in the siting and design phase to situate sediment traps for easy access by maintenance crews. This will allow for proper inspection and maintenance on a periodic basis. When excavating an area for sediment trap implementation, side slopes should not be steeper than 2:1 and embankment height should not exceed 5 feet from the original ground surface. All embankments should be machine compacted to ensure stability. To reduce flow rate from the trap, the outlet should be lined with well-graded stone.

The spillway weir for each temporary sediment trap should be at least 4 feet long for a 1-acre drainage area and increase by 2 feet for each additional drainage acre added, up to a maximum drainage area of 5 acres.

Limitations

Sediment traps should not be used for drainage areas greater than 5 acres (USEPA, 1993). The effective life span of these temporary structures is usually limited to 24 months (Smolen et al., 1988). Although sediment traps allow for settling of eroded soils, because of their short detention periods for storm water they typically do not remove fine particles such as silts and clays.

Maintenance Considerations

The primary maintenance consideration for temporary sediment traps is the removal of accumulated sediment from the basin. This must be done periodically to ensure the continued effectiveness of the sediment trap. Sediments should be removed when the basin reaches approximately 50 percent sediment capacity. A sediment trap should be inspected after each rainfall event to ensure that the trap is draining properly. Inspectors should also check the structure for damage from erosion. The depth of the spillway should be checked and maintained at a minimum of 1.5 feet below the low point of the trap embankment.

Effectiveness

Sediment trapping efficiency is a function of surface area, inflow rate, and the sediment properties (Smolen et al., 1988). Those traps that provide pools with large length-to-width ratios have a greater chance of success. Sediment traps have a useful life of approximately 18 to 24 months (USEPA, 1993), although ultimately effectiveness depends on the amount and intensity of rainfall and erosion, and proper maintenance. USEPA (1993) estimates an average total suspended solids removal rate of 60 percent. An efficiency rate of 75 percent can be obtained for most Coastal Plain and Piedmont soils by using the following equation (Barfield and Clar, in Smolen et al., 1988): Surface area at design flow (acres) = (0.01) peak inflow rate (cfs)

STORM DRAIN INLET PROTECTION

Description

Storm drain inlet protection measures are controls that help prevent soil and debris from site erosion from entering storm drain drop inlets. Typically, these measures are temporary controls that are implemented prior to large-scale disturbance of the surrounding site. These controls are advantageous because their implementation allows storm drains to be used during even the early stages of construction activities. The early use of storm drains during project development significantly reduces the occurrence of future erosion problems (Smolen et al., 1988).

Three temporary control measures to protect storm drain drop inlets are

- Excavation around the perimeter of the drop inlet
- Fabric barriers around inlet entrances
- Block and gravel protection.

Excavation around a storm drain inlet creates a settling pool to remove sediments. Weep holes protected by gravel are used to drain the shallow pool of water that accumulates around the inlet. A fabric barrier made of porous material erected around an inlet can create an effective shield to erosion sediment while allowing water flow into the storm drain. This type of barrier can slow runoff velocity while catching soil and other debris at the drain inlet. Block and gravel inlet protection uses standard concrete blocks and gravel to form a barrier to sediments while permitting water runoff through select blocks laid sideways.

In addition to the materials listed above, limited temporary storm water drop inlet protection can also be achieved with the use of straw bales or sandbags to create barriers to sediment. For permanent storm drain drop inlet protection after the surrounding area has been stabilized, sod can be installed as a barrier to slow storm water entry to storm drain inlets and capture erosion sediments. This final inlet protection measure can be used as an aesthetically pleasing way to slow storm water velocity near drop inlet entrances and to remove sediments and other pollutants from runoff.

Applicability

All temporary controls should have a drainage area no greater than 1 acre per inlet. It is also important for temporary controls to be constructed prior to disturbance of the surrounding landscape. Excavated drop inlet protection and block and gravel inlet protection are applicable to areas of high flow where overflow is anticipated into the storm drain. Fabric barriers are recommended for smaller, relatively flat drainage areas (slopes less than 5 percent leading to the storm drain). Temporary drop inlet control measures are often used in combination with each other and other storm water control techniques.

Siting and Design Considerations

With the exception of sod drop inlet protection, these controls should be installed before any soil disturbance in the drainage area. Excavation around drop inlets should be dug a minimum of 1 foot deep (2 feet maximum) with a minimum excavated volume of 35 yd^3 per acre disturbed. Side slopes leading to the inlet should be no steeper than 2:1. The shape of the excavated area should be designed such that the dimensions fit the area from which storm water is anticipated to drain. For example, the longest side of an excavated area should be along the side of the inlet expected to drain the largest area.

Fabric inlet protection should be staked close to the inlet to prevent overflow on unprotected soils. Stakes should be used with a minimum length of 3 feet, spaced no more than 3 feet apart. A frame should be constructed for fabric support during overflow periods and should be buried at least 1 foot below the soil surface and rise to a height no greater than 1.5 feet above ground. The top of the frame and fabric should be below the down-slope ground elevation to prevent runoff bypassing the inlet.

Block and gravel inlet barrier height should be 1 foot minimum (2 feet maximum), and mortar should not be used. The bottom row of blocks should be laid at least 2 inches below the soil surface flush against the drain for stability. One block in the bottom row should be placed on each side of the inlet on its side to allow drainage. Wire mesh (1/2 inch) should be placed over all block openings to prevent gravel from entering the inlet, and gravel (3/4 to 1/2 inch in diameter) should be placed outside the block structure at a slope no greater than 2:1.

Sod inlet protection should not be considered until the entire surrounding drainage area is stabilized. The sod should be laid so that it extends at least 4 feet from the inlet in each direction to form a continuous mat the around inlet, laying sod strips perpendicular to the direction of flows. The sod strips should be staggered such that strip ends are not aligned, and the slope of the sodded area should not be steeper than 4:1 approaching the drop inlet.

Limitations

Storm water drop inlet protection measures should not be used as stand-alone sediment control measures. To increase inlet protection effectiveness, these practices should be used in combination with other measures, such as small impoundments or sediment traps (USEPA, 1992). Temporary storm drain inlet protection is not intended for use in drainage areas larger than 1 acre. Generally, storm water inlet protection measures are practical for relatively low-sediment, low-volume flows. Frequent maintenance of storm drain control structures is necessary to prevent clogging. If sediment and other debris clog the water intake, drop intake control measures can actually cause erosion in unprotected areas.

Maintenance Considerations

All temporary control measures must be checked after each storm event. To maintain the sediment capacity of the shallow settling pools created from these techniques, accumulated sediment should be removed from the area around the drop inlet (excavated area, around fabric barrier, or around block structure) when the sediment capacity is reduced by approximately 50 percent. Additional debris should be removed from the shallow pools on a periodic basis. Weep holes in excavated areas around inlets can become clogged and prevent water from draining out of shallow pools that form. Should this happen, unclogging the water intake may be difficult and costly.

Effectiveness

Excavated drop inlet protection may be used to improve the effectiveness and reliability of other sediment traps and barriers, such as fabric or block and gravel inlet protection. However, as a whole, the effectiveness of inlet protection is low for erosion and sediment control, long-term pollutant removal, and low for habitat and stream protection.

GENERAL CONSTRUCTION SITE WASTE MANAGEMENT

Description

Building materials and other construction site wastes must be properly managed and disposed of to reduce the risk of pollution from materials such as surplus or refuse building materials or hazardous wastes. Practices such as trash disposal, recycling, proper material handling, and spill prevention and cleanup measures can reduce the potential for storm water runoff to mobilize construction site wastes and contaminate surface or ground water.

Applicability

The proper management and disposal of wastes should be practiced at any construction site to reduce storm water runoff. Waste management practices can be used to properly locate refuse piles, to cover materials that may be displaced by rainfall or storm water runoff, and to prevent spills and leaks from hazardous materials that were improperly stored.

Siting and Design Considerations

The following steps should be taken to ensure proper storage and disposal of construction site wastes:

- Designate a waste collection area onsite that does not receive a substantial amount of runoff from upland areas and does not drain directly to a waterbody.
- Ensure that containers have lids so they can be covered before periods of rain, and keep containers in a covered area whenever possible.
- Schedule waste collection to prevent the containers from overfilling.
- Clean up spills immediately. For hazardous materials, follow cleanup instructions on the package. Use an absorbent material such as sawdust or kitty litter to contain the spill.
    - During the demolition phase of construction, provide extra containers and schedule more frequent pickups.
    - Collect, remove, and dispose of all construction site wastes at authorized disposal areas. A local environmental agency can be contacted to identify these disposal sites.

The following steps should be taken to ensure the proper disposal of hazardous materials:

- Local waste management authorities should be consulted about the requirements for disposing of hazardous materials.
- A hazardous waste container should be emptied and cleaned before it is disposed of to prevent leaks.
- The original product label should never be removed from the container as it contains important safety information. Follow the manufacturer's recommended method of disposal, which should be printed on the label.

- If excess products need to be disposed of, they should never be mixed during disposal unless specifically recommended by the manufacturer.

State or local solid waste regulatory agencies or private firms should be consulted to ensure the proper disposal of contaminated soils that have been exposed to and still contain hazardous substances. Some landfills might accept contaminated soils, but they require laboratory tests first.

Paint and dirt are often removed from surfaces by sandblasting. Sandblasting grits are the byproducts of this procedure and consist of the sand used and the paint and dirt particles that are removed from the surface. These materials are considered hazardous if they are removed from older structures because they are more likely to contain lead-, cadmium-, or chrome-based paints. To ensure proper disposal of sandblasting grits, a licensed waste management or transport and disposal firm should be contracted.

The following practices should be used to reduce risks associated with pesticides or to reduce the amount of pesticides that come in contact with storm water:

- Follow all federal, state, and local regulations that apply to the use, handling, or disposal of pesticides.
- Do not handle the materials any more than necessary.
- Store pesticides in a dry, covered area.
- Construct curbs or dikes to contain pesticides in case of spillage.
- Follow the recommended application rates and methods.
- Have equipment and absorbent materials available in areas where pesticides are stored and used in order to contain and clean up any spills that occur.

The following management practices should be followed to reduce the contamination risk associated with petroleum products:

- Store petroleum products and fuel for vehicles in covered areas with dikes in place to contain any spills.
- Immediately contain and clean up any spills with absorbent materials.
- Have equipment available in fuel storage areas and in vehicles to contain and clean up any spills that occur.

Phosphorous- and nitrogen-containing fertilizers are used on construction sites to provide nutrients necessary for plant growth, and phosphorous- and nitrogen-containing detergents are found in wash water from vehicle cleaning areas. Excesses of these nutrients can be a major source of water pollution. Management practices to reduce risks of nutrient pollution include the following:

- Apply fertilizers at the minimum rate and to the minimum area needed.
- Work the fertilizer deeply into the soil to reduce exposure of nutrients to storm water runoff.
- Apply fertilizer at lower application rates with a higher application frequency.
- Limit hydroseeding, which is the simultaneous application of lime and fertilizers.
- Ensure that erosion and sediment controls are in place to prevent fertilizers and sediments from being transported off-site.
- Use detergents only as recommended, and limit their use onsite. Wash water containing detergents should not be dumped into the storm drain system—it should be directed to a sanitary sewer or be otherwise contained so that it can be treated at a wastewater treatment plant.

Limitations

An effective waste management system requires training and signage to promote awareness of the hazards of improper storage, handling, and disposal of wastes. The only way to be sure that waste management practices are being followed is to be aware of worker habits and to inspect storage areas regularly. Extra management time may be required to ensure that all workers are following the proper procedures.

Maintenance Considerations

Containers or equipment that may malfunction and cause leaks or spills should be identified through regular inspection of storage and use areas. Equipment and containers should be inspected regularly for leaks, corrosion, support or foundation failure, or any other signs of deterioration and should be tested for soundness. Any found to be defective should be repaired or replaced immediately.

Effectiveness
Waste management practices are effective only when they are regularly practiced at a construction site. Guidelines for proper handling, storage, and disposal of construction site wastes should be posted in storage and use areas, and workers should be trained in these practices to ensure that everyone is knowledgeable enough to participate.

SPILL PREVENTION AND CONTROL PLAN

Description
Spill prevention and control plans should clearly state measures to stop the source of a spill, contain the spill, clean up the spill, dispose of contaminated materials, and train personnel to prevent and control future spills.
Applicability
Spill prevention and control plans are applicable to construction sites where hazardous wastes are stored or used. Hazardous wastes include pesticides, paints, cleaners, petroleum products, fertilizers, and solvents.
Siting and Design Considerations
Identify potential spill or source areas, such as loading and unloading, storage, and processing areas, places where dust or particulate matter is generated, and areas designated for waste disposal. Also, spill potential should be evaluated for stationary facilities, including manufacturing areas, warehouses, service stations, parking lots, and access roads.
Define material handling procedures and storage requirements, and take actions to reduce spill potential and impacts on storm water quality. This can be achieved by

- Recycling, reclaiming, or reusing process materials and thereby reducing the amount of process materials that are brought into the facility
- Installing leak detection devices, overflow controls, and diversion berms
- Disconnecting any drains from processing areas that lead to the storm sewer
- Performing preventative maintenance on storm tanks, valves, pumps, pipes, and other equipment
- Using material transfer procedures or filling procedures for tanks and other equipment that minimize spills
- Substituting less or non-toxic materials for toxic materials.

Provide documentation of spill response equipment and procedures to be used, ensuring that procedures are clear and concise. Give step-by-step instructions for the response to spills at a particular facility. This spill response plan can be presented as a procedural handbook or a sign. The spill response plan should

- Identify individuals responsible for implementing the plan
- Define safety measures to be taken with each kind of waste
- Specify how to notify appropriate authorities, such as police and fire departments, hospitals, or publicly owned treatment works for assistance
- State procedures for containing, diverting, isolating, and cleaning up the spill
- Describe spill response equipment to be used, including safety and cleanup equipment.

Limitations
A spill prevention and control plan must be well planned and clearly defined so that the likelihood of accidental spills can be reduced and any spills that do occur can be dealt with quickly and effectively. Training might be necessary to ensure that all workers are knowledgeable enough to follow procedures. Equipment and materials for cleanup must be readily accessible and clearly marked for workers to be able to follow procedures.
Maintenance Considerations
Update the spill prevention and control plan to accommodate any changes in the site or procedures. Regularly inspect areas where spills might occur to ensure that procedures are posted and cleanup equipment is readily available.
Effectiveness
A spill prevention and control plan can be highly effective at reducing the risk of surface and ground water contamination. However, the plan's effectiveness is enhanced by worker training, availability of materials and equipment for cleanup, and extra time spent by management to ensure that procedures are followed.

VEHICLE MAINTENANCE & WASHING AREAS

Description

Maintenance and washing of vehicles should be conducted using environmentally responsible practices to prevent direct, untreated discharges of nutrient-enriched wastewater or hazardous wastes to surface or ground waters. This involves designating covered, paved areas for maintenance and washing, eliminating improper connections from these areas to the storm drain system, developing a spill prevention and cleanup plan for shop areas, maintaining vehicles and other equipment that may leak hazardous chemicals, covering fuel drums and other materials that are stored outdoors, and properly handling and disposing of automotive wastes and wash water.

Applicability

Environmentally friendly vehicle maintenance and washing practices are applicable for every construction site to prevent contamination of surface and ground water from wash water and fuel, coolant, or antifreeze spills or leaks.

Siting and Design Considerations

Construction vehicles should be inspected for leaks daily and repaired immediately. All used products, including oil, antifreeze, solvents, and other automotive-related chemicals, should be disposed of as directed by the manufacturer. These products are hazardous wastes that require special handling and disposal. Used oil, antifreeze, and some solvents can be recycled at a designated facility, but other chemicals must be disposed of at a hazardous waste disposal site. A local environmental agency can help to identify such facilities.

Special paved areas should be designated for a vehicle repair area and a separate vehicle washing area in which runoff and wastewater from these areas is directed to the sanitary sewer system or other treatment facility as industrial process waste. Vehicle washing facilities should use high-pressure water spray without any detergents as water can remove most dirt adequately. If detergents must be used, phosphate- or organic-based cleansers should be avoided to reduce nutrient enrichment and biological oxygen demand in wastewater. Only biodegradable products should be used—they should not contain halogenated solvents. If possible, blowers or vacuums should be used instead of water to remove dry materials from vehicles. Washing areas must be clearly marked and workers should be informed that all washing must occur in this area. No other activities, such as vehicle repairs, should be conducted in the wash area. If vehicles or equipment are heavily greased or soiled, the area should be bermed and covered to prevent contamination of runoff from these pollutants.

Limitations

Limitations for vehicle maintenance areas include the cost of waste disposal (a fee may be charged by a hazardous waste disposal facility), the cost of providing an enclosed maintenance area with proper connections to an industrial sanitary sewer, and extra labor required to follow proper storage, handling, and disposal procedures. Vehicle wash areas might require permits, depending on the volume of wastewater produced and the type of detergents used, and it might be expensive to designate an area for vehicle washing with proper connections to the industrial waste handling system.

Maintenance Considerations

Vehicle maintenance areas produce a substantial amount of hazardous waste that requires regular disposal. Spills must be cleaned up and cleanup materials disposed of immediately. Equipment and storage containers should be inspected regularly to identify leaks or signs of deterioration. Maintenance of vehicle wash areas is minimal and involves maintenance of berms and drainage to the sanitary sewer system.

Effectiveness

The techniques mentioned above are very effective at reducing discharges of untreated automotive wastes and wash water to receiving waters. Their effectiveness is highly dependent on the training and level of commitment of personnel to follow procedures.

CONSTRUCTION REVIEWER

Description

According to some state's regulations, the construction reviewer should be able to perform routine inspections of construction sites. According to the state of Delaware, the following guidelines should be followed by the construction reviewer:

- Perform a construction review of active construction sites at least once a week.

- Within five calendar days, inform the person engaged in the land-disturbing activity, and the contractor, by a written construction review report of any violations of the approved plan or inadequacies of the plan. Inform the plan approval agency, if the approved plan is inadequate, within five working days. In addition, send the appropriate construction review agency copies of all construction review reports.

    - Refer the project through the delegated inspection agency to the proper department for appropriate enforcement action if the person engaged in the land-disturbing activity fails to address the items contained in the written construction review report. Give verbal notice to the proper department.

Applicability

Construction reviewer training is considered an extremely important aspect of erosion and sediment control and stormwater enforcement. Construction reviewer training allows for third-party inspections of construction permits and BMP implementation. Third-party inspections free up state personnel from the time-consuming efforts to inspect each construction site. However, construction site reviewer training is still in its infant stages and is not yet a nationwide program.

Limitations

Several states do not have enough enforcement officers to inspect a large number of construction sites. The regulatory agency that oversees permits relies heavily on notifications by the public for permit noncompliance at construction sites. Because of some state's dependence on public involvement, numerous construction sites are not inspected.

Effectiveness

If the permit is reviewed by a regulatory agency or third party and the site is inspected on a regular basis, then it is assumed that the contractor certification is a success. For construction reviewers, the state of Delaware has produced a program that has proven both beneficial in protecting the environment and cost effective. The Delaware Department of Natural Resources and Environmental Control's (DNREC) Sediment and Storm Water Program illustrates how an aggressive inspection program depending on privately employed inspectors can limit the water quality impacts of construction. The result is a win-win situation in which the environment is protected, developers have less downtime, DNREC's workload is more reasonable, and local jobs are created. To obtain the mandated construction inspection, developers can hire one of the hundreds of private inspectors licensed under the state's Certified Construction Reviewer (CCR) program, first implemented in 1992.

In New Castle County, Delaware, a Phase I permitted county, the CCR program has been a successful component of the overall storm water management program. The county is enjoying economic growth and related commercial and residential development. Approximately 400 construction sites per year in Delaware require development and implementation of a detailed Sediment and Storm Water Plan. Limited to only three county government inspectors, the county has used the CCR program to leverage greater inspection coverage and increase compliance with federal, state, and local construction requirements. Of the 400 construction starts, more than 75 percent are being inspected by CCRs for at least a portion of the site development. The CCRs inspect active sites weekly and submit a report to the developer/contractor and to the county. County staff time once spent inspecting construction sites can now be spent overseeing the private CCR inspection process. Through the CCR program, New Castle County has saved approximately $100,000 annually, while the rate of compliance with Delaware's Sediment and Storm Water Program requirements has increased.

BMP INSPECTION AND MAINTENANCE

Description

To maintain the effectiveness of construction site storm water control best management practices (BMPs), regular inspection of control measures is essential. Generally, inspection and maintenance of BMPs can be categorized into two groups--expected routine maintenance and nonroutine (repair) maintenance. Routine maintenance refers to checks performed on a regular basis to keep the BMP in good working order and aesthetically pleasing. In addition, routine inspection and maintenance is an efficient way to prevent potential nuisance situations (odors, mosquitoes, weeds, etc.), reduce the need for repair maintenance, and reduce the chance of polluting storm water runoff by finding and correcting problems before the next rain.

Routine inspection should occur for all storm water and erosion and sediment control (ESC) measures implemented at a site. These measures may include, but are not limited to, grass-covered areas, seeded areas, mulched areas, areas stabilized with geotextiles or sod, silt fences, earth dikes, brush barriers, vegetated swales, sediment traps, sediment basins, subsurface drains, pipe slope drains, level spreaders, storm drain drop inlet protection measures, gabions, rain barrels, and road and site entrance stabilization measures.

Nonroutine maintenance refers to any activity that is not performed on a regular basis. This type of maintenance could include major repairs after a violent storm or extended rainfall, or replacement and redesign of existing control structures.

In addition to maintaining the effectiveness of storm water BMPs and reducing the incidence of pests, proper inspection and maintenance is essential to avoid the health and safety threats inherent in BMP neglect (Skupien, 1995). The failure of structural storm water BMPs can lead to downstream flooding, causing property damage, injury, and even death.

Applicability

All storm water BMPs should be inspected for continued effectiveness and structural integrity on a regular basis for the life of the construction project. Generally, all BMPs should be checked after each storm event in addition to the regularly scheduled inspections. Scheduled inspections vary between BMPs. Structural BMPs like storm drain drop inlet protection might require more frequent inspection than other BMPs to ensure proper operation. Inspection and maintenance of BMPs should continue until all construction activities have ended and all areas of a site have been permanently stabilized. During each inspection, the inspector should document whether the BMP is performing correctly, any damage to the BMP since the last inspection, and what should be done to repair the BMP if damage has occurred.

Siting and Design Considerations

In the case of vegetative or other infiltration BMPs, inspection of storm water management practices following a storm event should occur after the expected drawdown period for a given BMP. This approach allows the inspector to see whether detention and infiltration devices are draining correctly. Inspection checklists should be developed for use by BMP inspectors. The checklists might include each BMP's minimum performance expectations, design criteria, structural specifications, date of implementation, and expected life span. In addition, the maintenance requirements for each BMP should be listed on the inspection checklist. This checklist will aid the inspector in determining whether a BMP's maintenance schedule is adequate or needs revision. Also, a checklist will help the inspector determine renovation or repair needs.

Limitations

Routine maintenance materials such as shovels, lawn mowers, and fertilizer can be obtained on short notice with little effort. Unfortunately, not all materials that might be needed for emergency structural repairs are obtained with such ease. Thought should be given to stockpiling essential materials in case immediate repairs must be made to safeguard against property loss and to protect human health.

Maintenance Considerations

When considering a maintenance schedule for BMPs to control storm water runoff from construction activities, care should be taken to factor in increased erosion and sedimentation rates for construction sites. Clearing, grading, or otherwise altering the landscape at a construction site can increase the erosion rate by as much as 1,000 times the preconstruction rate for a given site (USEPA, 1992). Depending on the relative amount of disturbed area at a site, routine maintenance might have to occur on a more frequent basis.

It is important that routine maintenance and nonroutine repair of storm water and erosion control BMPs be done according to schedule or as soon as a problem is discovered. Because many BMPs are rendered ineffective for storm water runoff control if not installed and maintained properly, it is essential that maintenance schedules are maintained and repairs are performed promptly. In fact, in some cases BMP neglect can have detrimental effects on the landscape and increase the potential for erosion. However, "routine" maintenance such as mowing grass should be flexible enough to accommodate varying need based on weather conditions. For example, more harm than good might be caused by mowing during a drought or immediately after a storm event.

Effectiveness

The effectiveness of BMP inspection is a function of the familiarity of the inspector with each particular BMP's location, design specifications, maintenance procedures, and performance expectations.

Documentation should be kept regarding the dates of inspection, findings, and maintenance and repairs that result from the findings of an inspector. Such records are helpful in maintaining an efficient inspection and maintenance schedule and provide evidence of ongoing inspection and maintenance.

Because maintenance work for storm water BMPs (mowing, removal of sediment, etc.) is usually not technically complicated, workers can be drawn from a large labor pool. As structural BMPs increase in their sophistication, however, more specialized maintenance training might be needed to sustain BMP effectiveness.

Pollution Prevention/Good Housekeeping

Updated July 2008; February 2010

Metroparks owns, develops, operates and maintains, nearly 25,000 acres of parkland providing a wide variety of recreation and leisure activities and facilities for almost 10 million visitors a year. In order to provide patrons with accessible, well maintained facilities, park developments include roadways, parking lots, recreational site developments, equipment maintenance facilities, administrative, support and operations buildings and materials storage areas. The goal of this section is to develop and initiate operation and maintenance BPMs which will prevent or reduce pollutant runoff from these operations to the maximum extent practicable. The Metroparks has already implemented a multi-year program of constructing and upgrading its facilities in golf service yards and park service yards both in and outside of the Phase II regulated areas, for the purpose of improving the quality of storm water runoff. Pesticide loading buildings, salt storage buildings, enclosed vehicle wash bays, all with appropriate containment details, have been constructed over the last decade. The Metroparks has eliminated many existing building floor drain connections to storm systems, particularly in our service areas. This is a part of an overall effort of improving Metroparks facilities and to diminish potential storm water impacts including those areas within the parks not covered in the Phase II program.

The Metroparks recognizes that employee training is a key element in addressing pollutant reductions and will continue provide educational opportunities on the various aspects of pollution prevention. The development and implementation of BMPs is a critical component of the measure. In order to facilitate the implementation process, the Metroparks has initiated the use of EPA NPDES BMP guidelines in this pollution prevention process as indicated in the description section below and/or develop specific Metroparks BMPs as appropriate. In addition, the Metroparks has been involved in the Michigan Turfgrass Environmental Stewardship Program (MTESP) since its creation in 1998. The Michigan Turfgrass Environmental Stewardship Program is dedicated to protecting ground and surface water resources by advancing turfgrass management programs, developing pollution prevention techniques and promoting the understanding and compliance of state environmental laws and regulations. This program is a cooperative partnership between Michigan State University, Michigan Department of Agriculture, Michigan Department of Natural Resources & Environment, Golf Association of Michigan and the Michigan Turfgrass Foundation. The program focuses on education and assistance to the golf industry to assure compliance of state regulations including pesticide& fertilizer handling and storage, wellhead protection, fuel storage, enhancing and protection of wildlife habitat and protection of the states water resources.

Nine Metroparks golf courses are fully MTESP Certified with Kensington Metropark Golf Course being the first in the State of Michigan to achieve such Certification. To remain certified, property owners must continue with stated Best Management Practices, educational opportunities, regulation updates and participate in a program review every third year.

Task: Employee/Contractor Training.

Description: The Metroparks will ensure that training is made available to all appropriate staff and Contractors. Training will be provided to the appropriate people at least once during each permit cycle. New Contractors will have a training session prior to commencing work. New full time employees will have a training session within 1 year of employment.

Task: To develop and initiate operation and maintenance control measures which will prevent or reduce pollutant runoff from Metroparks operations to the maximum extent practicable.

Description: The Metroparks incorporate storm water management BMPs into its daily operations as a part of the good housekeeping practices that will address the discharge of pollutants to the storm water conveyances of Metroparks properties. Through proper employee training, the Metroparks continue to address good housekeeping and compliance issues including proper handling of wastes, chemicals, equipment and maintenance activities as well as identifying and reporting any storm water issues not in compliance with applicable regulations.

Where appropriate and feasible, the Metroparks implement storm water BMPs to minimize potential water quality impact of daily maintenance and operations activities at its facilities including.

- Storm drain systems. Each Park will routinely monitor, inspect and maintain storm water systems so that these systems provide effective pollution prevention to the maximum extent practicable. The Metroparks will also label and identify any new storm water discharge outfall as mandated by the Permit. Storm Water Quality Units will be inspected annually.
- Roadways, parking lots, sidewalks and trails. The Metroparks address issues relating to roadway construction and maintenance including road and parking lot design in order to minimize storm water runoff, the use of deicers and deicing activities, street cleaning, catch basin maintenance and illicit discharge elimination.
- General grounds maintenance, landscaped areas and golf courses. The Metroparks follow turf management plan for maintained areas, soil test for proper nutrient inputs, and insure proper handling and use of pesticides and fertilizers.
- Maintenance /Operations yards including fleet maintenance activities, equipment washing, fueling, and materials storage.

Responsibility: The Metroparks Planning and Engineering Departments are responsible for administration of the SWMPP, with program implementation being executed through Engineering, Purchasing, Food Services and Park Operations. In cooperation with Park Superintendents and the Human Resources Department, staff training and information regarding storm water management, operational BMPs and Permit requirements will be disseminated to appropriate park personnel. All inquiries regarding storm water management will be directed to Michel Arens, Chief Engineer and administrator for the Metroparks Phase II Storm Water Management Program Plan.

POLLUTION PREVENTION/ GOOD HOUSEKEEPING - BEST MANAGEMENT PRACTICES (BMPS)

Updated July 2008; February 2010

PET WASTE COLLECTION

Description

Pet waste collection as a source control involves using a combination of educational outreach and enforcement to encourage residents to clean up after their pets. The presence of pet waste in storm water runoff has a number of implications for urban stream water quality, with perhaps the greatest impact from fecal bacteria. According to recent research, nonhuman waste represents a significant source of bacterial contamination in urban watersheds. Genetic studies by Alderiso et al. (1996) and Trial et al. (1993) both concluded that 95 percent of fecal coliform found in urban storm water were of nonhuman origin. Bacterial source-tracking studies in a watershed in the Seattle, Washington, area also found that nearly 20 percent of the bacteria isolates that could be matched with host animals were matched with dogs. These bacteria can pose health risks to humans and other animals and result in the spread of disease. It has been estimated that for watersheds of up to 20 square miles draining to small coastal bays, 2 or 3 days of droppings from a population of about 100 dogs would contribute enough bacteria and nutrients to temporarily close a bay to swimming and shellfishing (USEPA, 1993).

Pet waste may also be a factor in the eutrophication of lakes. The release of nutrients from the decay of pet waste promotes weed and algae growth, limiting light penetration and the growth of aquatic vegetation. This situation, in turn, can reduce oxygen levels in the water, affecting fish and other aquatic organisms.

Pet waste collection programs use pet awareness and education, signs, and pet waste control ordinances to alert residents to the proper disposal techniques for pet droppings. In some parts of the country, the concept of parks or portions of parks established specifically for urban dog owners has gained in popularity. With provisions for proper disposal of dog feces and siting and design to address storm water runoff, these parks may represent another option for protecting local water quality.

Applicability

Pet ownership is not limited by factors such as region of the country, climate, or topography. For this reason, educational outreach regarding pet waste is appropriate throughout the country. In a survey of Chesapeake Bay residents, it was found that about 40 percent of households own a dog. Just about half of these dog owners actually walked their dog in public areas. Of the half that did walk their dog, about 60 percent claimed to pick up after their dog (Swann, 1999), which is generally consistent with other studies (Table 1). Men were found to be less prone to pick up after their dog than women were (Swann, 1999).

Residents seem to be of two minds when it comes to dog waste. While a strong majority agree that dog waste can be a water quality problem (Hardwick, 1997; Swann, 1999), they generally rank it as the least important local water quality problem (Syferd, 1995 and MSRC, 1997). This finding strongly suggests the need to dramatically improve watershed education efforts to increase public recognition about the water quality and health consequences of dog waste.

Table 1. A comparison of three resident surveys about cleaning up after dogs

Study	Survey Results
Maryland (HGIC, 1996)	• 62% always cleaned up after the dog, 23% sometimes, 15% never • Disposal method: trash can (66%), toilet (12%), other 22%
Washington (Hardwick, 1997)	• Pet ownership: 58% • 51% of dog owners do not walk dogs • 69% claimed that they cleaned up after the dog • 31% do not pick up • Disposal methods: trash can 54%, toilet 20%, compost

	pile 4% • 4% train pet to poop in own yard • 85% agreed that pet wastes contribute to water quality problems
Chesapeake Bay (Swann, 1999)	• Dog ownership: 41% • 44% of dog owners do not walk dogs • Dog walkers who clean up most/all of the time 59% • Dog walkers who never or rarely cleanup 41% • Of those who never or rarely clean up, 44% would not cleanup even with fine, complaints, or improved sanitary collection or disposal methods • 63% agreed that pet wastes contribute to water quality problems

Design Considerations

Programs to control pet waste typically use "pooper-scooper" ordinances to regulate pet waste cleanup. These ordinances require the removal and proper disposal of pet waste from public areas and other people's property before the dog owner leaves the immediate area. Often a fine is associated with failure to perform this act as a way to encourage compliance. Some ordinances also include a requirement that pet owners remove pet waste from their own property within a prescribed time frame.

Public education programs are another way to encourage pet waste removal. Often pet waste messages are incorporated into a larger non-point source message relaying the effects of pollution on local water quality. Brochures and public service announcements describe proper pet waste disposal techniques and try to create a storm drain-water quality link between pet waste and runoff. Signs in public parks and the provision of receptacles for pet waste will also encourage cleanup.

Another option for pet waste management could be the use of specially designated dog parks where pets are allowed off-leash. These parks typically include signs reminding pet owners to remove waste, as well as other disposal options for pet owners. The following management options have been used in Australian dog parks and could be incorporated for dog parks in the United States (Harlock Jackson et al., 1995):

- *Doggy loos*. These disposal units are installed in the ground and decomposition occurs within the unit. Minimal maintenance is required (no refuse collection).
- *Pooch patch*. A pole is placed in the park surrounded by a light scattering of sand. Owners are encouraged to introduce their dog to the pole on entry to the park. Dogs then return to the patch to defecate and special bins are provided in which owners then place the deposit.
- *The "Long Grass Principle."* Dogs are attracted to long grass for defecating and areas that are mowed less frequently can be provided for feces to disintegrate naturally. A height of around 10 cm (about 4 inches) is appropriate.

The design of these dog parks should be done to mitigate storm water impacts. The use of vegetated buffers, pooper-scooper stations, and the siting of parks out of drainageways, streams, and steep slopes will help control the impacts of dog waste on receiving waters.

Limitations

The reluctance of many residents to handle dog waste is the biggest limitation to controlling pet waste. According to a Chesapeake Bay survey, 44 percent of dog walkers who do not pick up indicated they would still refuse to pick up, even if confronted by complaints from neighbors, threatened with fines, or provided with more sanitary and convenient options for retrieving and disposing of dog waste. Table 2 provides factors that compel residents to pick up after their dog, along with some rationalizations for not doing so.

Table 2. Dog owners rationale for picking up or not picking up after their dog (Source: HGIC, 1996)

Reasons for not picking it up	**Reasons for picking up**
• because it eventually goes away	☐ it's the law

• just because • too much work • on edge of my property • it's in my yard • it's in the woods • not prepared • no reason • small dog, small waste • use as fertilizer • sanitary reasons • own a cat or other kind of pet	☐ environmental reasons ☐ hygiene/health reasons ☐ neighborhood courtesy ☐ it should be done ☐ keep the yard clean

This strong resistance to handling dog wastes suggests that an alternative message may be necessary. One such example might be to encourage the practice of rudimentary manure management by training dogs to use areas that are not hydraulically connected to the stream or close to a buffer.

Effectiveness

The pollutant removal abilities of pet waste collection programs has never been quantified. There is ample evidence that programs such as these are required in urban areas. For example, in the Four Mile Run watershed in Northern Virginia, a dog population of 11,400 is estimated to contribute about 5,000 pounds of solid waste every day and has been identified as a major contributor of bacteria to the stream. Approximately 500 fecal coliform samples have been taken from Four Mile Run and its tributaries since 1990, and about 50 percent of these samples have exceeded the Virginia State water quality standard for fecal coliform bacteria (NVRC, 2001). A project is currently underway to pinpoint the source of bacterial contamination through DNA fingerprinting.

There is plenty of evidence that pets and urban wildlife can be significant bacterial sources. According to van der Wel (1995) a single gram of dog feces can contain 23 million fecal coliform bacteria. Dogs can also be significant hosts of both *Giardia* and *Salmonella* (Pitt, 1998). A 1982 study of Baltimore, Maryland, catchments reported that dog feces were the single greatest contributor of fecal coliform and fecal strep bacteria (Lim and Olivieri, 1982). This evidence points to a need for enforcement and education to raise resident awareness regarding the water quality impacts of this urban pollutant source.

AUTOMOBILE MAINTENANCE

Description

This pollution prevention measure involves creating a program of targeted outreach and training for businesses and municipal fleets (public works, school buses, fire, police, and parks) involved in automobile maintenance about practices that control pollutants and reduce storm water impacts. Automotive maintenance facilities are considered to be storm water "hot spots" where significant loads of hydrocarbons, trace metals, and other pollutants can be produced that can affect the quality of storm water runoff. Some of the waste types generated at automobile maintenance facilities and at homes of residents performing their own car maintenance include the following:

- Solvents (paints and paint thinners)
- Antifreeze
- Brake fluid and brake lining
- Batteries
- Motor oils
- Fuels (gasoline, diesel, kerosene)
- Lubricating grease.

Estimates show that each year over 180 million gallons of used oil is disposed of improperly (Alameda CCWP, 1992) and that a single quart of motor oil can pollute 250,000 gallons of drinking water (DNREC, 1994). For this reason, automotive maintenance facilities' discharges to storm and sanitary sewer systems are highly regulated. Fluid spills and improper disposal of materials result in pollutants, heavy metals, and toxic materials entering ground and surface water supplies, creating public health and environmental risks. Alteration of practices involving the cleanup and storage of automotive fluids and cleaning of vehicle parts can help reduce the influence of automotive maintenance practices on storm water runoff and local water supplies.

Applicability

The automotive repair industry is the leader in number of generators and amount of total waste produced for small quantity generators of hazardous waste in the United States (USEPA, 1985). Common activities at maintenance shops that generate this waste include the cleaning of parts, changing of vehicle fluids, and replacement and repair of equipment. These activities are also performed by residents at home in their driveway in the course of normal vehicle care. Since the use of automobiles is not limited by geographic or climatic conditions, maintenance facilities are present nationwide and the concerns involving waste created during vehicle repair are similar across the country. In ultra-urban areas, the impacts of automotive maintenance practices are more pronounced due to the greater concentrations of vehicles and higher levels of impervious surface.

Design Considerations

The most effective way to minimize the impacts of automotive maintenance generated waste is by preventing its production. Pollution prevention programs seeking to reduce liquid discharges to sewer and storm drains from automotive maintenance should stress techniques that allow facilities to run a dry shop. Among the suggestions for creating a dry operation are the following:

- Spills should be cleaned up immediately, and water should not be used for clean up whenever possible.
- Floor drains that are connected to the sanitary sewer should be sealed off.
- A solvent service might be hired to supply parts and cleaning materials, and to collect the spent solvent.

Those facilities that are not able to eliminate discharges to the sanitary sewer system may be required to treat their wastewater prior to release from the site. There are several methods for preventing untreated wastewater from entering storm water runoff. Some municipalities require the use of structural treatment devices to pretreat wastes before they are discharged for treatment at sewage treatment plants. These devices prevent oils and grease from entering the sewer system, often by separating the oil and solids from the water through settling or filtration.

Other methods are also available to help prevent or reduce the discharge of pollutants from vehicle maintenance. Table 1 lists some of the common suggestions found regarding practices that can reduce vehicle maintenance and repair impacts. Many of these practices apply both to business owners and to residents who maintain their own vehicles. Additionally, these practices also apply to maintaining municipal fleets, including school buses, public works, fire, police, parks, and other types of municipal fleets. This list is not comprehensive, and many other suggestions for reducing impacts are available to those responsible for managing storm water runoff from maintenance facilities.

Table 1. Recommendations for reducing the storm water impacts of automotive maintenance

Pollution Prevention Method	**Suggested Activities**
Waste Reduction	• The number of solvents used should be kept to a minimum to make recycling easier and to reduce hazardous waste management cost. • Do all liquid cleaning at a centralized station to ensure that solvents and residues stay in one area. • Locate drip pans and draining boards to direct solvents back into solvent sink or holding tank for reuse.

Using Safer Alternatives	• Use non-hazardous cleaners when possible. • Replace chlorinated organic solvents with nonchlorinated ones like kerosene or mineral spirits. • Recycled products such as engines, oil, transmission fluid, antifreeze, and hydraulic fluid can be purchased to support the market of recycled products.
Spill Clean Up	• Use as little water as possible to clean spills leaks, and drips. • Rags should be used to clean small spills, dry absorbent material for larger spills, and a mop for general cleanup. Mop water can be disposed of via the sink or toilet to the sanitary sewer.
Good Housekeeping	• Employee training and public outreach are necessary to reinforce proper disposal practices. • Conduct maintenance work such as fluid changes indoors. • Update facility schematics to accurately reflect all plumbing connections. • Parked vehicles should be monitored closely for leaks and pans placed under any leaks to collect the fluids for proper disposal or recycling. • Promptly transfer used fluids to recycling drums or hazardous waste containers. • Do not pour liquid waste down floor drains, sinks, or outdoor storm drain inlets. • Obtain and use drain mats to cover drains in the event of a spill. • Store cracked batteries in leakproof secondary containers.
Parts Cleaning	• Use detergent-based or water-based cleaning systems instead of organic solvent degreasers. • Steam cleaning and pressure washing may be used instead of solvent parts cleaning. The wastewater generated from steam cleaning can be discharged to the on-site oil/water separator.

Limitations

There are a number of limitations to implementing recommendations for automotive maintenance facilities. Space and time constraints may make performing work indoors unfeasible. Containment of spills from vehicles brought on-site after working hours may not be possible. Proper disposal education for employees must continually be updated. Installation of structural BMPs for pretreatment of wastewater discharges can be expensive. Prices for recycled materials and fluids may be higher than those of non-recycled materials. Some facilities can be limited by a lack of providers of recycled materials and by the absence of businesses to provide services such as hazardous waste removal, structural BMP maintenance, or solvent recycling equipment.

Maintenance Considerations

For facilities responsible for pretreating their wastewater prior to discharging, the proper functioning of structural BMPs is an important maintenance consideration. Routine cleanout of oil and grease is required for the devices to maintain their effectiveness, usually at least once a month. During periods of heavy rainfall, cleanout is required more often to ensure that pollutants are not washed through the trap. Sediment removal is also required on a regular basis to keep the device working efficiently.

Effectiveness

The effectiveness of automotive maintenance best management practices at removing pollutants is difficult to quantify. However, there are studies that demonstrate the effect pollution prevention practices can have in reducing impacts from automotive fluids. A 1994 study of auto recycling facilities demonstrates the effect that using best management practices can have on reducing storm water toxicity and pollutant loads. Through the use of structural and nonstructural BMPs, the study facility was able to reduce concentrations of lead, oil, and grease to levels approaching USEPA benchmarks.

A program that has had great success in controlling contaminated flows from vehicle maintenance facilities is the Clean Bay Business Program in Palo Alto, California. In exchange for allowing inspectors to visit a facility once a year and implementing recommended management practices, the facility is designated as a Clean Bay Business. This entitles the facility to promotional tools like listings twice a year in full-page newspaper ads, decals for shop windows, and other Clean Bay Business materials. Other promotions involving prize drawings and discount coupon giveaways help generate business for the facilities in the program. The effectiveness of the program at creating behavioral changes is evident in the increase in the number of facilities that have received the Clean Bay Business designation. In 1992 when the program began, only 4 percent of businesses used all of the recommended management practices. By 1998, 94 percent of businesses had instituted the practices suggested (NRDC, 1999).

The effectiveness of those programs aimed at altering behaviors detrimental to storm water is impressive. After participation in the program, the changes facilities made had the following impacts:

- 78 direct discharges to storm drains were eliminated by ceasing or modifying the practices used for activities such as parking lot cleaning, vehicle washing, and wet sanding.
- Violations of storm drain protection requirements fell by 90 percent from 1992 through 1995.
- The number of shops conducting outdoor removal of vehicle fluids without secondary containment fell from 43 to 4.

VEHICLE WASHING

Description

This management measure involves educating the general public, businesses, and municipal fleets (public works, school buses, fire, police, and parks) on the water quality impacts of the outdoor washing of automobiles and how to avoid allowing polluted runoff to enter the storm drain system. Outdoor car washing has the potential to result in a high loads of nutrients, metals, and hydrocarbons during dry weather conditions in many watersheds, as the detergent-rich water used to wash the grime off our cars flows down the street and into the storm drain. Commercial car wash facilities often recycle their water or are required to treat their wash water discharge prior to release to the sanitary sewer system, so most storm water impacts from car washing are from residents, businesses, and charity car wash fundraisers that discharge polluted wash water to the storm drain system. According to the surveys, 55 to 70 percent of households wash their own cars, with the remainder going to a commercial car wash. Sixty percent of residents could be classified as "chronic car-washers" who wash their cars at least once a month (Smith, 1996, and Hardwick, 1997). Between 70 and 90 percent of residents reported that their car wash water drained directly to the street and, presumably, to the nearest stream. It has been estimated that 25 percent of the population of the United States may be classified as chronic car washers, which translates into about 27 million potential residential car wash polluters (Center for Watershed Protection, 1999).

Applicability

Car washing is a common routine for residents and a popular way for organizations such as scout troops, schools, and sports teams to raise funds. This activity is not limited by geographic region, but its impact on water quality is greatest in more urbanized areas with higher concentrations of automobiles. Currently, only a few pollution prevention programs incorporate proper car washing practices as part of an overall message to residents on ways to reduce nonpoint source pollution. Other programs have extended this message to include charity car washes and provide these charity groups with equipment and training to alleviate the problems associated with polluted wash water entering the storm drain system.

Implementation

The development of a prevention program to reduce the impact of car wash runoff includes outreach on management practices to reduce discharges to storm drains. Some of these management practices include the following:

- Using a commercial car wash.
- Washing cars on gravel, grass, or other permeable surfaces.
- Blocking off the storm drain during charity carwash events or using a insert to catch wash water.
- Pumping soapy water from car washes into a sanitary sewer drain.
- If pumping into a drain is not feasible, pumping car wash water onto grass or landscaping to provide filtration.
- Using hoses with nozzles that automatically turn off when left unattended.
- Using only biodegradable soaps.

Storm drain stenciling programs (see the Storm Drain Stenciling fact sheet) emphasizing the connection between the storm drain system and runoff can also help reinforce the idea that car washing activities can affect local water quality.

In the Pacific Northwest, outreach programs provide materials to charity carwash organizers to prevent car wash water from entering storm drains. These "water friendly "carwash kits are provided free of charge to charity organizers, along with training and educational videos on planning an environmentally friendly carwash. Two types of equipment are available for charity organizations to borrow: a catch-basin insert with a sump pump, or a vacuum/boom device known as a Bubble Buster (Kitsap County, 1999). Both devices capture wash water runoff, allowing it to be pumped to either a sanitary sewer or a vegetated area for treatment.

For businesses, good housekeeping practices can minimize the risk of contamination from wash water discharges. The following are some general best management practices that those businesses with their own vehicle washing facilities can incorporate to control the water quality impacts of wash water discharges:

- All vehicle washing should be done in areas designed to collect and hold the wash and rinse water or effluent generated. Wash water effluent should be recycled, collected, or treated prior to discharge to the sanitary sewer system.
- Pressure cleaning and steam cleaning should be done off-site to avoid generating runoff with high pollutant concentrations. If done on-site, no pressure cleaning and steam cleaning should be done in areas designated as wellhead protection areas for public water supply.
- On-site storm drain locations should be mapped to avoid discharges to the storm drain system.
- Spills should be immediately contained and treated.

Limitations

The biggest limitation to implementing residential car wash best management practices may be the lack of knowledge regarding the impacts of polluted runoff. Many people do not associate the effects of their vehicle washing activities with local water quality and may be unaware that the discharges that enter storm drains are not treated at plants before being discharged into local waters. Surveys indicate that the average citizen does not fully understand the hydrologic connection between their yard, the street, the storm sewer, and the streams. For example, a recent Roper survey found that just 22 percent of Americans know that storm water runoff is the most common source of pollution of streams, rivers, and oceans (NEETF, 1999).

Most car washing best management practices are inexpensive and rely more on good housekeeping practices than on expensive technology. However, the construction of a specialized area for vehicle washing can be expensive for businesses. Also, for facilities that cannot recycle their wash water, the cost of pretreating wash water, through either structural practices or planning for collection and hauling of contaminated water to sewage treatment plants, can represent a cost limitation.

Effectiveness

The effectiveness of car washing management practices at reducing nonpoint source pollutant loads has yet to be measured accurately. Due to the diffuse nature of nonpoint source pollution, it is often difficult to determine the exact impact of a particular pollution prevention measure at reducing pollutant loading. While not much is known about the water quality of car wash water, it is clear that car washing is a common watershed behavior. Three recent surveys have asked residents where and how frequently they wash their cars (Table 2).

Table 2. A comparison of three surveys about car washing.

Study	**Car Washing Behavior**
Smith, 1996 Maryland	60% washed car more than once a month
Pellegrin, 1998 California	73% washed their own cars 73% report that wash-water drains to pavement
Hardwick, 1997 Washington	56% washed their own cars 44% used a commercial car wash 91% report that wash-water drains to pavement 56% washed car more than once a month 50% would shift if given discounts or free commercial car washes

Residents are typically not aware of the water quality consequences of car washing and do not understand the chemical content of the soaps and detergents they use. Car washing is a very difficult watershed behavior to change since it is often hard to define a better alternative. However, as with all pollution prevention measures, the reduction of pollutant loads from outdoor car washing activities are bound to have a positive effect on storm water quality.

ILLEGAL DUMPING CONTROL

Description

Illegal dumping control as a management practice involves using public education to familiarize residents and businesses with how illegal dumping can affect storm water. By locating and correcting illegal dumping practices through education and enforcement measures, the many risks to public safety and water quality associated with illegal disposal actions can be prevented. For storm water managers, illegal dumping control is important to preventing contaminated runoff from entering wells and surface water, as well as averting flooding due to blockages of drainage channels for runoff.

Several types of illegal dumping can occur. The first is the illegal dumping (also known as "open dumping," "fly dumping," or "midnight dumping") of litter that occurs at abandoned industrial, commercial, or residential buildings, vacant lots, and poorly lit areas such as rural roads and railway lines. This dumping primarily happens to avoid disposal fees or the time and effort required for proper disposal at landfills or recycling facilities. A second type of illegal dumping involves disposal of water that has been exposed to industrial activities and then released to the storm drainage system, introducing pollutants into storm water runoff.

Applicability

Illegal dumping can occur in both urban and rural settings and can happen in all geographic regions. The effects of illegal dumping may be more pronounced in areas with heavier rainfall, due to the greater volume of runoff. In more urbanized areas, illegal dumping may occur due to inaccessibility of recycling or solid waste disposal centers, which are often located on the suburban-rural fringe.

Design Considerations

Illegal dumping control programs focus on community involvement and targeted enforcement to eliminate or reduce illegal dumping practices. The key to successfully using this BMP is increasing public awareness of the problem and its implications. Illegal dumping control programs use a combination of public education, citizen participation, site maintenance, and authorized enforcement measures to address illegal waste disposal. Some of the issues that need to be examined when creating a program include the following:

- The locations of persistent illegal dumping activity
- Types of waste dumped and the profile of dumpers
- Possible driving forces behind illegal dumping, such as excessive user fees, restrictive curbside trash pickup, or ineffective recycling programs
- Previous education and cleanup efforts
- Current control programs and local laws or ordinances addressing the problem
- Sources of funding and additional resources that may be required.

Effective illegal dumping control programs use practices that educate and involve the community, local industries, and elected officials in an effort to eliminate the illegal discarding of wastes. An EPA toolkit for preventing illegal dumping focuses on four programmatic areas (USEPA 1998):

1. <u>Cleanup efforts</u>

Cleanup projects will require a coordinated planning effort to ensure that adequate resources and funding are available. Once a site has been cleaned, signs, lighting, or barriers may be required to discourage future dumping. Signs should indicate the fines and penalties for illegal dumping, and a phone number for reporting incidents. Landscaping and beautification efforts might also discourage future dumping, as well as providing open space and increasing property values.

2. <u>Community Outreach and Involvement</u>

This might be the most important tool in ensuring that this best management practice is effective. The organization of special cleanup events where communities are provided with the resources to properly dispose of illegally dumped materials increases the understanding among residents of illegal dumping impacts and supplies opportunities to correctly dispose of materials which may otherwise be illegally dumped. Integration of illegal dumping prevention into community policing programs or use of programs such as Crimestoppers may also be an effective way to increase enforcement opportunities without the additional cost of hiring new staff. Producing simple messages relating the cost of illegal dumping on local taxes, and directions to proper disposal sites will aid in eliminating the problem. Having a hotline where citizens can report illegal activities and educating the public on the connection between the storm drain and water quality will decrease disposal of waste into storm drain inlets.

3. <u>Targeted Enforcement</u>

This tool involves the use of ordinances to regulate waste management and eliminate illegal dumping through methods such as fines, cost recovery penalties for cleanup, and permit requirements for waste management activities. These fines and penalties can be used to help fund the prevention program or to provide rewards to citizens who report illegal dumping activities. Other recommendations for this tool include training of staff from all municipal departments in recognizing and reporting illegal dumping incidents, and dedicating staff who have the authority to conduct surveillance and inspections and write citations for those caught illegally dumping.

4. <u>Tracking and Evaluation</u>

This tool measures the impact of prevention efforts and determines if goals are being met. Using mapping techniques and computer databases allows officials to identify areas where dumping most often occurs, record patterns of dumping occurrence (time of day, day of week, etc.), and calculate the number of citations issued to the responsible parties. This allows for better allocation of resources and more specific targeting of outreach and education efforts for offenders.

Limitations

Illegal dumping is often spurred by cost and convenience considerations, and a number of factors encourage this practice. The cost of fees for dumping at a proper waste disposal facility are often more than the fine for an illegal dumping offense, thereby discouraging people from complying with the law. The absence of routine or affordable pickup service for trash and recyclables in some communities also encourages illegal dumping. A lack of understanding regarding applicable laws or the inadequacy of existing laws may also contribute to the problem.

Municipalities can coordinate with state and federal agencies to help enforce illegal dumping control measures when resources such as funding and staff for enforcement activities are scarse.

Effectiveness

While the effectiveness of illegal dumping control measures at removing pollutant loads to local waters is hard to quantify, there are numbers to demonstrate the preventative effects these programs have in keeping waste from illegal dump sites and ultimately from storm water runoff. Some examples follow:

- The City/County of Spokane, Washington, Litter Control program is responsible for removing indiscriminate dumping on publicly owned properties and road right-of-ways. The program is estimated to remove 350 tons of illegally dumped material each year.
- Project HALT in Phoenix, Arizona, cleaned up a reported 15,000 tons of waste in 1996 and 1997 and issued more than 165 citations.
- The "Tire Roundup" program sponsored by the Southwest Detroit Environmental Visions community organization pays local residents to bring in illegally dumped tires. In 1995, residents were paid 25 cents per tire, and more than 8,000 tires were collected.

Illegal dumping of household and commercial waste has a variety of impacts on water quality. Hazardous chemicals generated from household, commercial, and industrial sources can contaminate ground and surface water supplies, affecting drinking water and public health as well as aquatic habitat. Reduced drainage of runoff due to blockage of streams, culverts and drainage basins can result in flooding and channel modification. Open burning associated with some illegal sites can cause forest fires that create severe erosion and cause sediment loading in streams. Economically, property values decrease as a result of illegal dumping and affect the local tax base and the ability to maintain pollution prevention programs.

LANDSCAPING AND LAWN CARE

Description

This management measure seeks to control the storm water impacts of landscaping and lawn care practices through education and outreach on methods that reduce nutrient loadings and the amount of storm water runoff generated from lawns. Research has indicated that nutrient runoff from lawns has the potential to cause eutrophication in streams, lakes, and estuaries (CWP, 1999a, and Schueler, 1995a). Nutrient loads generated by suburban lawns as well as municipal properties can be significant, and recent research has shown that lawns produce more surface runoff than previously thought (CWP, 1999b). Pesticide runoff (see Pest Control fact sheet) can contribute pollutants that contaminate drinking water supplies and are toxic to both humans and aquatic organisms.

Landscaping, lawn care, and grounds maintenance are a big business in the United States. It has been estimated that there are 25 to 30 million acres of turf and lawn in the United States (Robert and Roberts, 1989, Lawn and Landscape Institute, 1999). If lawns were classified as a crop, they would rank as the fifth largest in the country on the basis of area, after corn, soybeans, wheat, and hay (USDA, 1992). In terms of fertilizer inputs, nutrients are applied to lawns at about the same application rates as those used for row crops (Barth, 1995a). The urban lawn is also estimated to receive an annual input of 5 to 7 pounds of pesticides per acre (Schueler, 1995b).

Not many residents understand that lawn fertilizer can cause water quality problems overall, less than one-fourth of residents rated it as a water quality concern (Syferd, 1995 and Assing, 1994), although ratings were as high as 60 percent for residents who lived adjacent to lakes (Morris and Traxler, 1996, and MCSR, 1997). Interestingly, in one Minnesota survey, only 21 percent of homeowners felt their own lawn contributed to water quality problems, while over twice as many felt that their neighbors' lawns did (MCSR, 1997). Unlike farmers, suburban and rural landowners are often ignorant of the actual nutrient needs of their lawns. According to surveys, only 10 to 20 percent of lawn owners take the trouble to take soil tests to determine whether fertilization is even needed (CWP, 1999). The majority of lawn owners are not aware of the phosphorus or nitrogen content of the fertilizer they apply (Morris and Traxler, 1996) or that mulching grass clippings into lawns can reduce or eliminate the need to fertilize. Informing residents, municipalities, and lawn care professionals on methods to reduce fertilizer and pesticide application, limit water use, and avoid land disturbance can help alleviate the potential impacts of a major contributor of nonpoint source pollution in residential communities.

Applicability
Lawn care, landscaping, and grounds maintenance are done in all parts of the country, in all types of climates, and in every type of community from rural to urban. Lawn fertilization is one of the most widespread watershed practices conducted by homeowners. In a survey of resident attitudes in the Chesapeake Bay, 89 percent of residents owned a yard, and of these, about 50 percent applied fertilizer every year (Swann, 1999). The average rate of fertilization in 10 other resident surveys was even higher, at 78 percent, although this could reflect the fact that these surveys were biased toward predominantly suburban neighborhoods, or excluded non-lawn owners. Because lawn care, landscaping, and grounds maintenance are such common practices, education programs for both residents, municipalities, and lawn care professionals on reducing the storm water impacts of these practices are an excellent way to improve local water quality.
Design Considerations
Designers of education programs that seek to change the impacts of fertilizer, pesticide, and herbicide use on receiving water quality should first consider creating training programs for those involved in the lawn care industry. Nationally, lawn care companies are used by 7 to 50 percent of consumers, depending on household income and lot size. Lawn care companies can exercise considerable authority over which practices are applied to the lawns they tend, as long as they still produce an attractive lawn. For example, 94 percent of lawn care companies reported that they had authority to change practices, and that about 60 percent of their customers were "somewhat receptive to new ideas", according to a Florida study (Israel et al., 1995). De Young (1997) also found that suburban Michigan residents expressed a high level of trust in their lawn care company.
Local governments that want to influence lawn care companies must have an active program that supports those companies that employ techniques to limit fertilizer and pesticide use to the minimum necessary to maintain a green lawn. One way to do this is through providing promotional opportunities. One example is the state of Virginia Water Quality Improvement program that includes the chance for lawn care professionals to enter into an agreement to use more environmentally friendly lawn care practices. In exchange, the lawn care company can use their participation in the program as a promotional tool (VA DCR, 1999). Providing certification for representatives from lawn care companies for attending training workshops put on by cooperative extension offices can also be an effective promotional tool.
Training for employees of lawn and garden centers is another important tool in spreading the message regarding lawn care and pollution control. Many studies indicate that product labels and store attendants are the primary and almost exclusive source of lawn care information for the average consumer who takes care of their own lawn. The Florida Yards and Neighbors program has worked with 19 stores of a large national hardware and garden chain to educate store employees and incorporate messages regarding fertilizer use and pesticide reduction (NRDC, 1999). Often the key strategy to implementing a program like this is to substitute watershed-friendly products for those that are not, and to offer training for the store attendants at the point of sale on how to use and, perhaps more importantly, how not to abuse or overuse such products.
A recent Center for Watershed Protection (CWP) survey of 50 nutrient education programs provides a number of tips to program managers on making outreach programs more effective. The results of the study showed that there were a number of important considerations for increasing the recall and implementation of pollution prevention messages. Table 1 provides some tips that appear to work the best at relaying pollution prevention messages and changing pollution-producing behaviors.

Table 1. Tips for creating more effective resident lawn care outreach programs

Tip 1: *Develop a stronger connection between the yard, the street, the storm, and the stream.*	Outreach techniques should continually stress the link between lawn care and the undesirable water quality it helps to create (e.g., algae blooms and sedimentation).
Tip 2: *Form regional media campaigns.*	Since most communities operate on small budgets, they should consider pooling their resources to develop regional media campaigns that can use the outreach techniques that are proven to reach and influence residents. In particular, regional campaigns allow communities to hire the professionals needed to create and

	deliver a strong message through the media. Also, the campaign approach allows a community to employ a combination of media, such as radio, television, and print, to reach a wider segment of the population. It is important to keep in mind that since no single outreach technique will be recalled by more than 30 percent of the population at large, several different outreach techniques will be needed in an effective media campaign.
Tip 3: *Use television wisely*.	Television is the most influential medium for influencing the public, but careful choices need to be made on the form of television that is used. The CWP survey found that community cable access channels are much less effective than commercial or public television channels. Program managers should consider using cable network channels targeted for specific audiences, and develop thematic shows that capture interest of the home, garden and lawn crowd (e.g., shows along the lines of "Gardening by the Yard"). Well-produced public service announcements on commercial television are also a sensible investment.
Tip 4: *Keep messages simple and funny*.	Watershed education should not be preachy, complex, or depressing. Indeed, the most effective outreach techniques combine a simple and direct message with a dash of humor.
Tip 5: *Make information packets small, slick, and durable*.	Educators continually struggle about how to impart the detailed information to residents on how to really practice good lawn care behaviors, without losing their interest. One should avoid creating a ponderous and boring handbook. One solution is to create small, colorful and durable packets that contain the key essentials about lawn care behaviors, and direct contact information to get better advice. These packets can be stuck on the refrigerator, the kitchen drawer or the workbench for handy reference when the impulse for better lawn care behavior strikes.
Tip 6: *Understand the demographics of your watershed*.	Knowing the unique demographics of a watershed allows a program manager to determine what outreach techniques are likely to work for that particular area. For example, if some residents speak English as a second language, a certain percentage of outreach materials should be produced in their native language. Similarly, watershed managers should consider more direct channels to send watershed messages to reach particular groups, such as through church leaders or ethnic-specific newspapers and television channels**.**

Pollution prevention programs may also wish to incorporate a much stronger message that promotes a low- or zero-input lawn. Watershed education programs might strongly advocate no chemical fertilization, reduced turf area, and the use of native plants adapted to the ecoregion (Barth, 1995b). This message provides a balance to the pro-fertilization message that is marketed by the lawn care industry.

Program managers need to incorporate some method for evaluating the effectiveness of their programs at reaching residents. Many programs use "before and after" market surveys to provide information on the level of understanding of residents and the percentage of residents that implement good lawn care practices. These surveys provide insights on what outreach techniques work best for a community and the level of behavior change that can be expected.

Alternative landscaping techniques such as naturescaping and xeriscaping can also be used. *Xeriscaping* is considered to be a viable alternative to the high water requirements of typical landscaping. It is a form of landscaping that conserves water and protects the environment. Xeriscaping does not result in landscaping with cactus and rock gardens. Rather, cool, green landscapes can be used when they are maintained with water-efficient practices. The main benefit of xeriscaping is that it reduces water use (TAMU, 1996). Xeriscaping incorporates seven basic principles that reduce water use (NYDEP, 1997):

- *Planning and design*. Consider drainage, light, and soil conditions; desired maintenance level; which existing plants will remain; plant and color preferences; and budget.
- *Soil improvement*. Mix peat moss or compost into soil before planting to help the soil retain water. Use terraces and retaining walls to reduce water run-off from sloped yards.
- *Appropriate plant selection*. Choose low-water-using flowers, trees, shrubs, and groundcovers. Many of these plants need watering only in the first year.
- *Practical lawns*. Limit the amount of grass area. Plant groundcovers or add hard surface areas like decks, patios, or walkways. If replanting lawns, use drought-tolerant grass seed mixes.
- *Efficient irrigation*. Install drip or trickle irrigation systems, as they use water efficiently.
- *Effective use of mulches*. Use a 3-inch deep layer of mulches such as pine needles or shredded leaves or bark. This keeps soil moist, prevents erosion, and smothers weeds.
- *Appropriate maintenance*. Properly timed fertilizing, weeding, pest control, and pruning will preserve the beauty of the landscape and its water efficiency.

Naturescaping is a way of putting native plants and beneficial wildlife habitat back into your yard or community. It is also a beautiful way to conserve water and energy, reduce pollution of water and soil, and create habitat for wildlife. Native plants are the foundation of naturescaping. The plants that evolved in your region are well adapted to our climate and naturally resistant to local pests and diseases. Once established, natives can often survive on rainwater alone. Naturescaping areas can include replacing some lawn area with a wildflower meadow; hummingbird and butterfly garden, plants and trees selected for seeds, fruit, and nectar; and nesting boxes.

When creating a naturescape, it is important to include four elements: food, water, shelter, and adequate space. When creating a naturescape in your yard or community, keep in mind these steps:

- Visit "wild" places and naturescaped sites and imagine how these landscapes would fit in your yard or community.
- Educate yourself and your community. Learn about native plants and basic design and care concepts. You can attend workshops and read plant and design books.
- When you are ready to develop a site plan, choose a small viewable site. When planning, consider maintenance water, gardening, access to feeders. Know the existing conditions of the area shade/sun, wet/dry, wind patterns, drainage, existing plants and critters. Once you develop a plan and you have gotten any necessary permits, you are ready to gather your material and begin.

A local government can meet with local neighborhood and creek groups to promote community naturescaping, host naturescaping workshops, and establish naturescaping demonstration sites in neighborhoods, and can offer naturescaping assistance to many residential, business, and public projects.

Integrated Pest Management (IPM) is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. IPM programs use current, comprehensive information on the life cycles of pests and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment.

The IPM approach can be applied to both agricultural and nonagricultural settings, such as the home, garden, and workplace. IPM takes advantage of all appropriate pest management options, including -- but not limited to -- the judicious use of pesticides. In contrast, *organic* food production applies many of the same concepts as IPM but limits the use of pesticides to those that are produced from natural sources, as opposed to synthetic chemicals.

IPM is not a single pest control method but, rather, a series of pest management evaluations, decisions, and controls. Integrated pest management is a sustainable approach to managing pests by combining biological, cultural, physical, and chemical tools. Municipalities can encourage homeowners to practice IPM and train/encourage municipal maintenance crews to use these techniques for managing public green areas. There are many methods and types of integrated pest management, including the following:

- Mulching can be used to prevent weeds where turf is absent, fencing installed to keep rodents out, and netting used to keep birds and insects away from leaves and fruit.
- Visible insects can be removed by hand (with gloves or tweezers) and placed in soapy water or vegetable oil. Alternatively, insects can be sprayed off the plant with water or in some cases vacuumed off of larger plants.
- Store-bought traps, such as species-specific, pheromone-based traps or colored sticky cards, can be used.
- Sprinkling the ground surface with abrasive diatomaceous earth can prevent infestations by soft-bodied insects and slugs. Slugs also can be trapped in small cups filled with beer that are set in the ground so the slugs can get in easily.
- In cases where microscopic parasites, such as bacteria and fungi, are causing damage to plants, the affected plant material can be removed and disposed of. (Pruning equipment should be disinfected with bleach to prevent spreading the disease organism.)
- Small mammals and birds can be excluded using fences, netting, tree trunk guards.
- Beneficial organisms, such as bats, birds, green lacewings, ladybugs, praying mantis, ground beetles, parasitic nematodes, trichogramma wasps, seedhead weevils, and spiders that prey on detrimental pest species can be promoted.

Limitations

The overriding public desire for green lawns is probably the biggest impediment to limiting pollution from this source. For example, when residents were asked their opinions on more than 30 statements about lawns in a Michigan survey, the most favorable overall response was to the statement "a green, attractive lawn is an important asset in a neighborhood" (De Young, 1997). Nationally, homeowners spend about $27 billion each year to maintain their own yard or to pay someone else to do it (PLCAA, 1999). In terms of labor, a majority of homeowners spend more than an hour a week taking care of the lawn (Aveni, 1994, De Young, 1997). Convincing residents that a nice, green lawn can be achieved without using large amounts of chemicals and fertilizers is difficult when conventional lawn care techniques are often seen as more effective, less time-consuming, and more convenient.

Effectiveness

The effectiveness of pollution prevention programs designed to educate residents on lawn care and landscaping practices has not been well documented to date. However, the need for such programs is evident. Source area monitoring in Marquette, Michigan, found that nitrogen and phosphorus concentrations in residential lawn runoff were 5 to 10 times higher than from any other source area (CWP, 1999). This report confirms earlier Wisconsin research findings that residential lawns yielded the highest phosphorus concentrations of 12 urban pollutant sources examined (Bannerman et al, 1993).

A critical step in crafting an education program is to select the right outreach techniques to send the lawn care message. From the results of a number of market surveys, two outreach techniques have shown some promise in actually changing behavior -- media campaigns and intensive training. Media campaigns typically use a mix of radio, TV, direct mail, and signs to broadcast a general watershed message to a large audience. Intensive training uses workshops, consultation, and guidebooks to send a much more complex message to a smaller and more interested audience. Intensive training requires a more substantial time commitment, ranging from several hours to a few days.

From evaluations of several market surveys, it appears that media campaigns and intensive training can each produce up to a 10- to 20-percent improvement in selected watershed behaviors among their respective target populations. A combination of both outreach techniques is probably needed in most watersheds, as each complements the other. For example, media campaigns cost just a few cents per watershed resident reached, while intensive training can cost several dollars for each resident that is actually influenced. Media campaigns are generally better at increasing awareness and sending messages about negative watershed behaviors. Intensive training, on the other hand, is superior at changing individual practices in the home, lawn, and garden.

PEST CONTROL

Description

This management measure involves limiting the impact of pesticides on water quality by educating residents and businesses on alternatives to pesticide use and proper storage and on application techniques. The presence of pesticides in storm water runoff has a direct impact on the health of aquatic organisms and can present a threat to humans through contamination of drinking water supplies. The pesticides of greatest concern are insecticides, such as diazinon and chloropyrifos (CWP, 1999 and Schueler, 1995), which even at very low levels can be harmful to aquatic life. A recent study of urban streams by the U.S. Geological Survey found that some of the more commonly used household and garden insecticides occurred at higher frequencies and concentrations in urban streams than in agricultural streams (USGS, 1999). The study also found that these insecticide concentrations were frequently in excess of USEPA guidelines for protection of aquatic life.

The major source of pesticides to urban streams is home application of products designed to kill insects and weeds in the lawn and garden. It has been estimated that an average acre of a well-maintained urban lawn receives an annual input of 5 to 7 pounds of pesticides (Schueler, 1995). Pesticide pollution prevention programs try to limit adverse impacts of insecticides and herbicides by providing information on alternative pest control techniques other than chemicals or explaining how to determine the correct dosages needed to manage pests. Lawn care and landscaping management programs often include pesticide use management as part of their outreach message.

Applicability

EPA estimates that nearly 70 million pounds of active pesticide ingredients are applied to urban lawns each year. Table 1 compares surveys on residential pesticide use in eleven different areas of the country, broken down by insecticides and herbicides use. It appears that pesticide application rates vary greatly, ranging from a low of 17 percent to a high of 87 percent, but climate is an important factor in determining insecticide and herbicide use.

Table 1. A comparison of eleven surveys of residential insecticide and weedkiller use

Study	Number of Respondents	% Using Insecticides	% Using Herbicides
Chesapeake Bay Swann, 1999	656	21%	–
Maryland, Kroll and Murphy,1994	403	42%	32%
Virginia, Aveni, 1998	100	66%	–
Maryland, Smith, 1994	100	23%	n/a
Minnesota, Morris and Traxler, 1997	981	–	75%
Michigan, De Young, 1997	432	40%	59%
Minnesota, Dindorf, 1992	136	–	76%
Wisconsin, Kroupa, 1995	204	17%	24% **
Florida,	659	83%	–

Knox et al, 1995			
Texas, NSR, 1998	350	87%	–
California, Scanlin and Cooper, 1997	600	50%	–
Notes: (**) note difference in self-reported herbicide use and those that use a weed and feed product (herbicide combined with fertilizer)			

Insecticides appear to be applied more widely in warm weather climates where insect control is a year-round problem (such as Texas, California, and Florida). Anywhere from 50 to 90 percent of residents reported that they had applied insecticides in the last year in warm-weather areas. This can be compared to 20 to 50 percent levels of insecticide use reported in colder regions, where hard winters can help keep insects in check. By contrast, herbicide application rates tend to be higher in cold weather climates to kill the weeds that arrive with the onset of spring (60 to 75 percent in the Michigan, Wisconsin, and Minnesota surveys).

Design Considerations

The use of integrated pest management (IPM) is a popular way for program managers to educate residents and businesses on alternatives to chemical pesticides. IPM reflects a holistic approach to pest control that examines the interrelationship between soil, water, air, nutrients, insects, diseases, landscape design, weeds, animals, weather, and cultural practices to select an appropriate pest management plan. The goal of an IPM program is not to eliminate pests but to manage them to an acceptable level while avoiding disruptions to the environment. An IPM program incorporates preventative practices in combination with nonchemical and chemical pest controls to minimize the use of pesticides and promote natural control of pest species. Three different nonchemical pest control practices biological (good bugs that eat pests), cultural (handpicking of pests, removal of diseased plants, etc.), and mechanical (zappers, paper collars, etc) are used to limit the need for chemicals. In those instances when pesticides are required, programs seek to have users try less toxic products such as insecticidal soaps. The development of higher tolerance levels among residents for certain weed species is a central concept of IPM programs for reducing herbicide use.

Education on the proper use of pesticides is often included in many lawn care and landscaping management programs. Most often this is in the form of informational brochures or fact sheets on pesticide use around the home or garden. These information packets include tips on identifying pest problems and selecting treatment approaches that reduce environmental impacts; less-toxic pest control products if chemical control is necessary; and the proper mixing, application rates, and cleanup procedures for pesticide use. Program managers can consult cooperative extension programs and university agricultural programs for more information regarding pest control techniques that are more water quality friendly.

Limitations

The public perception that no alternative to pesticide use exists is probably the greatest limitation that program managers will face. Surveys tell us that the public has a reasonably good understanding about the potential environmental dangers of pesticides. Several surveys indicate that residents do understand environmental concerns about pesticides, and consistently rank them as the leading cause of pollution in the neighborhood (Elgin DDB, 1996). Even so, pesticide use still remains high in many urban areas (see Table 1). The time required for homeowners to learn more about alternative pest control techniques may also limit program effectiveness. Many residents prefer the ease of spraying a chemical on their lawns to other pest control techniques they perceive as more time intensive and less reliable. Managers should recognize that IPM programs have their own limitations, including questions about the effectiveness of alternative pest control techniques.

Effectiveness

A national study of the effectiveness of alternative pest control programs at reducing pesticide use and protecting water quality has not yet been performed. Cooperative extension and university agriculture programs across the country have performed studies of the ability of distinct alternative pest control techniques at limiting pesticide use, but a synthesis of these individual studies into a national report has not been performed. However, the need for pesticide control programs is evident from recent studies on the presence of insecticides in storm water. Results of recent sampling of urban streams caused the USGS to conclude that the presence of insecticides in urban streams may be a significant obstacle to restoring urban streams. (USGS, 1999). Table 2 examines eight studies on storm water runoff and insecticide concentrations and provides an example of how insecticides persist even after their use is discontinued.

Additional research done in the San Francisco Bay Region regarding diazinon use further illustrates the need for pest control programs. Results of the study show that harmful diazinon levels can be produced in urban streams from use at only a handful of individual homes in a given watershed (CWP, 1999). Due to the solubility of diazinon, current storm water and wastewater treatment technologies cannot significantly reduce diazinon levels. The best tool for controlling diazinon in urban watersheds is through source control by educating residents and businesses on pesticide alternatives and safe application.

An example of successful use of IPM is the Grounds Maintenance Program for the City of Eugene, Oregon. This program was started in the early 1980's and includes all the city public parks and recreation areas. The city uses a variety of IPM methods, including water blasting to remove aphids, insecticidal soaps, and limited use of pesticides. The city has also adopted higher tolerance levels for certain weed and pest species that reduces the need to apply pesticides and herbicides. Since the program's inception, pesticide usage by the City of Eugene has dropped bay more than 75 percent (Lehner et. al., 1999). Although no exact cost savings have been calculated from the use of the IPM program, the city turf and grounds supervisor believes the program saves money and has little citizen opposition.

Table 2: Banned or restricted insecticides found in storm water runoff concentrations in µg/l (ppb) (Source: Schueler, 1995)

Study	**Chlordane**	**Lindane**	**Dieldrin**	**Other**
Baltimore Kroll/Murphy	0.52	0.18	2.44	–
Rhode Island Cohen	Detected	NA	NA	NA
Atlanta Hippe	NA	0.01 (0.048)	NA	–
Atlanta Thomas	Detected	NX	NX	heptachlor
Milwaukee Bannerman	Detected	Detected	Detected	DDT, DDE
Washington MWCOG	0.2	0.2	0.2	heptachlor
Northern Virginia Dewberry and Davis	ND	Trace	ND	Endrin
Toronto D'Andrea	NA	0.5 to 2	0.1 to 2	–
Toronto D'Andrea	NA	0.5 to 2	0.1 to 2	–
ND=Not Detected, NA=Not Analyzed, NX= Detection reported only if they exceeded water quality standards.				

PARKING LOT AND STREET CLEANING

Description

This management measure involves employing pavement cleaning practices such as street sweeping on a regular basis to minimize pollutant export to receiving waters. These cleaning practices are designed to remove from road and parking lot surfaces sediment debris and other pollutants that are a potential source of pollution impacting urban waterways (Bannerman, 1999). Although performance monitoring for the Nationwide Urban Runoff Program (NURP) indicted that street sweeping was not very effective in reducing pollutant loads (USEPA, 1983), recent improvements in street sweeper technology have enhanced the ability of present day machines to pick up the fine grained sediment particles that carry a substantial portion of the storm water pollutant load. Many of today's sweepers can now significantly reduce the amount of street dirt entering streams and rivers, some by significant amounts (Runoff Report, 1998). A debate as to whether this ability to pick up finer particles will improve the overall pollutant removal effectiveness of street sweepers is ongoing, and further research is required to establish the optimal sweeping frequency for pollutant removal and what streets are most appropriate for a sweeping program.

Applicability

Street sweeping is practiced in most urban areas, often as an aesthetic practice to remove sediment buildup and large debris from curb gutters. In colder climates, street sweeping is used during the spring snowmelt to reduce pollutant loads from road salt and to reduce sand export to receiving waters. Seventy percent of cold climate storm water experts recommend street sweeping during the spring snowmelt as a pollution prevention measure (CWP, 1997). The frequency and intensity of rainfall for a region are also key variables in determining how streets need to be swept to obtain a desired removal efficiency. Other factors that affect a street sweeper's ability to reduce nonpoint pollution include the condition of the street, its geographical location, the operator's skill, the presence of parked cars, and the amount of impervious area devoted to rooftop.

Design Considerations

One factor considered most essential to the success of street sweeping as a pollutant removal practice is use of the most sophisticated sweepers available. Innovations in sweeper technology have improved the performance of these machines at removing finer sediment particles, especially for machines that use vacuum-assisted dry sweeping to remove particulate matter. By using the most sophisticated sweepers in areas with the highest pollutant loads, greater reductions in sediment and accompanied pollutants can be realized.

Another important aspect of street sweeping programs is the ability to regulate parking. The ability to impose parking regulations in densely populated areas and on heavily traveled roads is essential.

The frequency and location of street sweeping is another consideration for any program. How often and what roads to sweep are determined by the program budget and the level of pollutant removal the program wishes to achieve. Computer modeling of pollutant removal in the Pacific Northwest suggests that the optimum sweeping frequency appears to be once every week or two (CWP, 1999). More frequent sweeping operations yielded only a small increment in additional removal. The model also suggests that somewhat higher removal could be obtained on residential streets as opposed to more heavily traveled arterial roads.

Sweeping of parking lots is also employed as a nonstructural management practice for industrial sites. This sweeping involves using brooms to remove small quantities of dry chemicals and solids from areas that are exposed to rainfall or storm water runoff. While the effectiveness of this practice at pollutant removal is unknown, the sweeping and proper disposal of materials is a reasonably inexpensive method of pollution prevention that requires no special training or equipment.

Limitations

For street sweeping, the high cost of current sweeper technologies is a large limitation to using this management practice. With costs approaching $200,000 for some of the newer sweeper technologies, storm water managers with limited budgets must consider the high equipment cost together with the uncertainty about pollutant removal efficiency to decide whether a sweeping program is an attractive management option. The potential inability to restrict parking in urban areas may present another limitation. Other possible limitations include the need for sweeper operator training, the inability of current sweeper technology to remove oil and grease, and the lack of solid evidence regarding the expected levels of pollutant removal. Proper disposal of swept materials might also be a limitation.

Maintenance Considerations

Street cleaning programs require a significant investment of capital and a yearly operation and maintenance budget. Sweepers have a useful life of about four years, and proper maintenance can greatly improve sweeping efficiency. Arrangements for disposal of the swept material collected must also be made, as well as accurate tracking of the streets swept and the frequency of sweeping. The operation and maintenance costs for two types of sweepers are included in Table 1.

Effectiveness

Street sweeping programs had largely fallen out of favor as a pollutant removal practice following the 1983 NURP report, but improvements in sweeper technology have caused a recent reevaluation of their effectiveness. New studies show that conventional mechanical broom and vacuum-assisted wet sweepers reduce nonpoint pollution by 5 to 30 percent and nutrient content by 0 to 15 percent. However, newer dry vacuum sweepers can reduce nonpoint pollution by 35 to 80 percent and nutrients by 15 to 40 percent for those areas that can be swept (Runoff Report, 1998). While actual reductions in storm water pollutants have not yet been established, information on the reductions in finer sediment particles that carry a significant portion of the storm water pollutant load is available. Recent estimates are that the new vacuum assisted dry sweeper might achieve a 50–88 percent overall reduction in the annual sediment loading for a residential street, depending on sweeping frequency (Bannerman, 1999).

A benefit of high-efficiency street sweeping is that by capturing pollutants before they are made soluble by rainwater, the need for structural storm water control measures might be reduced. Structural controls often require costly added measures, such as adding filters to remove some of these pollutants and requiring regular manpower to change-out filters. Street sweepers that can show a significant level of sediment removal efficiency may prove to be more cost-effective than certain structural controls, especially in more urbanized areas with greater areas of pavement.

ROADWAY AND BRIDGE MAINTENANCE

Description

This practice involves pollution prevention techniques that reduce or eliminate pollutant loadings from existing road surfaces as part of an operation and maintenance program. Substantial amounts of sediment and pollutants are generated during daily roadway and bridge use and scheduled repair operations, and these pollutant loadings can threaten local water quality by contributing heavy metals, hydrocarbons, sediment, and debris to storm water runoff. Table 1 shows some of the constituents that can be present in highway runoff and their primary sources.

As Table 1 demonstrates, numerous pathways for pollutant deposition on roadways and bridges influence the water quality of storm water runoff. Routine performance of general maintenance activities such as sweeping, vegetation maintenance, and cleaning of runoff control structures can help alleviate the impacts of these pollutants. Modifications in roadway resurfacing practices and application techniques for salt and other deicers can also help reduce pollutant loads to storm water runoff and protect the quality of receiving waters.

Applicability

Roadway systems are a large part of the infrastructure of urban areas across the country, and require regular repairs and maintenance due to traffic use and climatic conditions. The level of pollutants found in road and bridge runoff is variable and is determined by a number of factors in addition to traffic volume and climate. Other factors affecting pollutant levels include surrounding land use, the design of the bridge or roadway, the presence of roadside vegetation, the use of insecticides, and the frequency of accidents and spills that can introduce hazardous chemicals. In colder climates, the amount of deicer applied to melt ice and snow can also influence the level of certain pollutants in road runoff and its impacts on local water quality.

Table 1. Highway runoff constituents and their primary sources (Source: USEPA, 1993)

Constituent	**Primary Sources**
Particulates	Pavement wear, vehicles, atmosphere
Nitrogen, Phosphorus	Atmosphere, roadside fertilizer application
Lead	Tire wear, auto exhaust
Zinc	Tire wear, motor oil, grease
Iron	Auto body rust, steel highway structures, moving engine parts
Copper	Metal plating, brake lining wear, moving engine parts, bearing and bushing wear, fungicides and insecticides
Cadmium	Tire Wear, insecticides
Chromium	Metal plating, moving engine parts, brake lining wear
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, brake lining wear, asphalt paving
Manganese	Moving engine parts
Cyanide	Anticake compound used to keep deicing salt granular
Sodium, Calcium, Chloride	Deicing salts
Sulphate	Roadway beds, fuel, deicing salts
Petroleum	Spills, leaks or blow-by of motor lubricants, antifreeze and hydraulic fluids, asphalt surface leachate

Design Considerations

Road and bridge maintenance programs have a number of options for reducing the level of pollutants generated during the maintenance of existing road surfaces. Changes in the methods used for maintaining road surfaces, removing debris and sediment from roadways, and cleaning of runoff control structures can help improve the overall quality of storm water discharges from roads and bridges.

Proper planning for road and bridge resurfacing operations is a simple but effective method to control pollution. Many techniques can be implemented to control the impacts of this maintenance operation. First, paving operations should be performed using concrete, asphalt, or other sealers only in dry weather situations to prevent contamination of runoff. Second, proper staging techniques should be used to reduce the spillage of paving materials during the repair of potholes and worn pavement. These techniques can include covering storm drain inlets and manholes during paving operations; using erosion and sediment control measures to decrease runoff from repair sites; and utilizing pollution prevention materials such as drip pans and absorbent material for all paving machines to limit leaks and spills of paving materials and fluids. Finally, resurfacing operations could employ porous asphalt for pothole repair and for shoulder areas to reduce the level of storm water runoff from road systems. For more information on permeable road surface materials, see the Porous Pavement fact sheet.

Good cleaning practices can help diminish impacts to storm water runoff. Sweeping and vacuuming of heavily traveled roadways to remove sediment and debris can reduce the amount of pollutants in runoff. Street sweeping as a pollution source control is discussed more extensively in the Parking Lot and Street Cleaning fact sheet. Regular cleaning of runoff control structures such as catch basins can help reduce sediment loads in runoff that will end up in local waterways (see Catch Basins fact sheet).

Proper application of road salt or other deicers also reduces storm water pollution. By routinely calibrating spreaders, a program manager can prevent over-application of deicing materials. In addition to reducing the effects of these materials on the aquatic environment, cost savings may be realized due to reductions in the purchase of deicing materials. Training for transportation employees in proper deicer application techniques, the timing of deicer application, and what type of deicer to apply will also determine the impacts on water quality and aquatic habitat.

Maintenance practices for roadside vegetation also determine the storm water quality of road runoff. Restrictions on the use of herbicides and pesticides on roadside vegetation, and training to ensure that employees understand the proper handling and application of pesticides and other chemicals, can help prevent contamination of runoff. Selection of roadside vegetation with higher salt tolerances will also help to maintain vegetated swales and biofilters that filter out runoff. For more information on vegetated storm water practices, see the Grassed Filter Strips fact sheet.

Bridge runoff may require additional maintenance practices to eliminate storm water runoff impacts. In addition to some of the roadway practices listed above improved, practices in bridge siting and design can help reduce water quality impacts. One technique is to avoid using bridge scupper drains for any new bridges and to routinely clean existing ones to prevent sediment and debris buildup. Scupper drains can cause direct discharges to surface waters and have been found to carry relatively high concentrations of pollutants (CDM, 1993). Program managers should consider endorsing retrofits of scupper drains with catch basins or redirecting water from these drains to vegetated areas to provide treatment. Other techniques such as using suspended tarps, booms, and vacuums to capture pollutants (e.g., paint, solvents, rust, and paint scrapings) generated during bridge maintenance will also help reduce impacts to receiving waters. In addition, using deicers such as glycol, urea, or calcium magnesium acetate (CMA) reduces the corrosion of metal bridge supports that can occur when salt is used.

Limitations

Generally, limitations to instituting pollution prevention practices for road and bridge maintenance involve the cost for additional equipment and training. Since maintenance of roadways and bridges is already required in all communities, staffing is usually in place and alteration of current practices should not require additional staffing or administrative labor.

Limitations may arise in the location of new bridges. The availability and cost of land and other economic and political factors may dictate where the placement of a new bridge will occur. Better design of the bridge to control runoff is required if it is being placed near sensitive waters. The practice of controlling paved areas to limit impervious surface might also be restricted by community regulations of required widths for roadways and shoulders.

Effectiveness

Limited data are available on the actual effectiveness of road and bridge maintenance practices at removing pollutants from storm water runoff. Table 2 examines the effectiveness and cost of some of the operation and maintenance practices recommended for storm water pollution control.

Table 2. Road and bridge maintenance management practices: cost and effectiveness (Source: USEPA, 1993)

	Effectiveness (% Removal)[a]		**Cost**
Maintaining Roadside Vegetation	Sediment Control: 90% average P and N: 40% average COD, Lead, and Zinc: 50% average TSS: 60% average		Natural succession allowed to occur Average: $100/acre/year Range: $50-$200/acre/year
Street Sweeping	Smooth Street Frequent Cleaning: TSS: 20% COD: 5% Lead: 25%	Smooth Street Infrequent Cleaning: TSS: N/A COD: N/A Lead: 5%	Average: $20/curb mile Range: $10–$30/curb mile

Litter Control	N/A	All are accepted as economical practices to control or prevent storm water impacts.
General Maintenance	N/A	
Minimizing Deicer Application	N/A	

[a]P=phosphorus; N=nitrogen; TSS=total suspended solids; COD=chemical oxygen demand

Although data may be limited on cost and effectiveness, preventative maintenance and strategic planning are time-proven and cost-effective methods to limit contamination of storm water runoff. It can be assumed that the management practices recommended will have a positive affect on storm water quality by working to reduce pollutant loads and the quantity of runoff. Protecting and restoring roadside vegetation, removal of debris and sediment from roads and bridges, and directing runoff to vegetated areas are all effective ways to treat storm water runoff. Other practices, such as minimizing deicer application, litter control, and proper handling of fertilizers, pesticides, and other toxic materials, work to control some of the pathways of storm water pollution. Employing good road and bridge maintenance practices is an efficient and low-cost means of eliminating some of the impacts of pollutants associated with road systems on local streams and waterways

STORM DRAIN SYSTEM CLEANING

Description

Storm drain systems need to be cleaned regularly. Routine cleaning reduces the amount of pollutants, trash, and debris both in the storm drain system and in receiving waters. Clogged drains and storm drain inlets can cause the drains to overflow, leading to increased erosion (Livingston et al., 1997). Benefits of cleaning include increased dissolved oxygen, reduced levels of bacteria, and support of instream habitat. Areas with relatively flat grades or low flows should be given special attention because they rarely achieve high enough flows to flush themselves (Ferguson et al., 1997).

Applicability

This measure is applicable to all storm drain systems. The same principles can be applied to material and waste handling areas, paved and vegetated areas, waterways, and new development projects (Ferguson et al., 1997).

Limitations

While cleaning is necessary for all storm drain systems, there are limitations (adapted from Ferguson et al., 1997) as follows:

- Cleaning the storm drain by flushing is more successful for pipes smaller than 36 inches in diameter.
- A water source is necessary for cleaning. The wastewater must be collected and treated once flushed through the system.
- Depending on the condition of the wastewater, it may or may not be disposed to sanitary sewer systems.
- The efficiency of storm system flushing decreases when the length of sewer line being cleaned exceeds 700 feet.

Maintenance Considerations

Ferguson et al. (1997) report removal of 55 to 65 percent for nonorganic materials and grits and 65 to 75 percent for organics.

ALTERNATIVE DISCHARGE OPTIONS FOR CHLORINATED WATER

Description

Chlorinated water discharged to surface waters has an adverse impact on local water quality. Swimming pools are a major source of chlorinated water discharged into sanitary and storm sewer systems. An average swimming pool holds 19,000 gallons of chlorinated water. Pools have high concentrations of chlorine, which is toxic to wildlife and fish.

Applicability

Many pool owners who live in cooler climates drain their swimming pools to reduce maintenance and potential damage from freezing during harsh winters. These individuals should not discharge pool water to the storm sewer system or directly into a waterbody and should investigate alternative discharge options.

Siting and Design Considerations

The Oregon Department of Environmental Quality suggests that

- Pool owners obtain permission from local sanitary sewer operators or municipal treatment plant operators and discharge to the sanitary sewer system.
- Discharge the chlorinated water to land, where it will not drain to local surface waters.
- Dechlorinate the water before draining the pool.

Montgomery County, Maryland's, Department of Environmental Protection (1997) provides the following guidelines to pool owners and operators:

- Community pools must discharge to the sanitary sewer using a surge tank.
- Residential pools must discharge backwash water to the sanitary sewer.
- If the only option for draining pool water is to discharge directly into the environment, water quality must comply with the applicable water quality criteria.
- Pool water must sit for at least 2 days after the addition of chlorine or bromine or until chlorine or bromine levels are below 0.1 mg/l.
- The pH of discharge water must be between 6.5 and 8.5 before it is discharged.
- Algicides such as copper or silver can interrupt normal algal and plant growth and should not be used.
- Total suspended solids must be below 60 mg/l—suspended particles should be allowed to settle out and the water should not appear murky. Settled material should not be discharged with pool water.
- Discharges to the environment should be directed over a land surface so that some level of filtration by soil particles can occur. The above water quality requirements also apply to land-applied water.

Limitations

Enforcement of safe discharge of chlorinated water may be difficult to achieve

ALTERNATIVE PRODUCTS

Description

Using alternatives to toxic substances drastically reduces their presence in storm water and receiving waters. The most common toxic substances found in the home are cleaners, automotive products, and pesticides. Fertilizers, paints, and fuels are among other common hazardous substances frequently found in ground water because of improper disposal (WEF and ASCE, 1998).

Applicability

The promotion of safer alternative products should be coupled with other programs designed to reduce the presence of hazardous or toxic materials in homes and storm water runoff. Examples of such programs are hazardous materials collection, good housekeeping or material management practices, oil and automotive waste recycling, and spill response and prevention (WEF and ASCE, 1998).

Examples of commonly used products and safer alternatives are as follows (adapted from Washington State Department of Ecology):

- *Aerosols*. Pump-type or non-aerosol products should be used.
- *Art supplies*. One should purchase water-based paints or inks. They should not contain lead or other toxic materials.
- *Batteries*. Rechargeable batteries are a cost-effective alternative to disposable batteries.
- *Chemical fertilizers*. Composting yard clippings and food scraps is an option. Manure (in measured amounts) is another alternative to chemical fertilizers.

- *Gasoline*. Not driving at all is the best way to reduce gasoline use. Purchasing a super-efficient or electric vehicle is the next best alternative. Carpooling, walking, bicycling, and public transportation are other viable options.
- *Motor Oil*. Re-refined motor oil should be used. Doing so will spur the market for recycled motor oil and decrease reliance on new oil supplies.
- *Pesticides*. Keeping homes and gardens free from food and breeding areas for insect pests prevents the need for pesticides. Onion, garlic, and marigold plants help keep garden pests at bay.

Implementation

One of the best ways to encourage homeowners to switch to alternatives to potentially harmful products is to educate them (see Proper Disposal of Household Hazardous Wastes fact sheet). Municipalities can compile a list of alternative products and post it on their web site, publish it in a newsletter, include it as an insert in a utility bill, or produce magnets or other household products with a select list of nonhazardous alternatives. Municipalities might choose to include commercially available products that have been shown to be "green" alternatives to harsh chemicals.

Limitations

In some cases, alternative products may not be readily available. In addition, cost can be a limiting factor. For example, until recently, environmentally friendly de-icing materials for roads were significantly more expensive than traditional salt (Babcock 1998). Effectiveness of alternatives may be an issue.
The biggest impediment to instituting widespread use of alternative products is public awareness. Municipal staff must convince people to change old habits or to try new products.

Effectiveness

The use of alternative products prevents their hazardous waste counterparts from being disposed of improperly and contaminating storm water.

Hazardous Materials Storage

Description

Failure to properly store hazardous materials dramatically increases the probability that they will end up in local waterways. Many people have hazardous chemicals stored throughout their homes, especially in garages and storage sheds. Practices such as covering hazardous materials or even storing them properly, can have dramatic impacts.

Applicability

Hazardous material storage is relevant to both urban and rural settings and all geographic regions. The effects of hazardous material leakage may be more pronounced in areas with heavier rainfall, due to the greater volume of runoff.

Siting and Design Considerations

EPA (1992) has outlined some management considerations for hazardous materials. They are as follows:

- Ensuring sufficient aisle space to provide access for inspections and to improve the ease of material transport.
- Storing materials well away from high-traffic areas to reduce the likelihood of accidents that might cause spills or damage to drums, bags, or containers.
- Stacking containers in accordance with the manufacturers' directions to avoid damaging the container or the product itself.
- Storing containers on pallets or equivalent structures. This facilitates inspection for leaks and prevents the containers from coming into contact with wet floors, which can cause corrosion. This consideration also reduces the incidence of damage by pests (insects, rodents, etc.).
- Delegating the responsibility for management of hazardous materials to personnel trained and experienced in hazardous substance management.

Covering hazardous materials and areas where such materials are handled reduces potential contact with storm water and wind. Storage areas, outdoor material deposits, loading and unloading areas, and raw materials should all be covered or enclosed. Priority should be given to locations of the most hazardous substances (USEPA 1992).

Residents waiting to dispose of their household hazardous waste should store it properly until their hazardous waste collection day (Kopel,1998). One storage technique requires a plastic container with a lid (e.g., a 5-gallon bucket). The container should be filled halfway with (unused) kitty litter. The hazardous substance in its own original container should be put into the kitty litter-filled plastic bucket. The bucket lid should be fastened, and the contained marked clearly, kept far away from children, and anyone else who might ingest it. Corrosion will be reduced if the container is stored on a shelf, rather than on a concrete or dirt floor.

Limitations

The lifespan of the cover or structure must be taken into account, depending on the hazardous nature of the stored materials. Tarpaulins and plastic sheets may not last in certain types of climatic conditions. If a roof or other structure is required, the lifespan will increase. Any storage facility must meet local fire and building codes (Ferguson, et al. 1997).

Maintenance Considerations

Maintenance of hazardous material storage areas consists mostly of inspection and employee training (Ferguson, et al. 1997). Storage spaces and containers should be routinely inspected for leaks, signs of cracks or deterioration, or any other signs of release.

Effectiveness

Improved storage of hazardous materials is effective at reducing contamination of storm water runoff and receiving waters if proper storage and maintenance techniques are used.

ROAD SALT APPLICATION AND STORAGE

Description

The application and storage of deicing materials, most commonly salts such as sodium chloride, can lead to water quality problems for surrounding areas (Koppelman et al., 1984). Salts, gravel, sand, and other materials are applied to highways and roads to reduce the amount of ice during winter storm events. Salts lower the melting point of ice, allowing roadways to stay free of ice buildup during cold winters. Sand and gravel increase traction on the road, making travel safer.

Applicability

This practice is applicable to areas that receive snowfall in winter months and require deicing materials. Municipalities in these areas must ensure proper storage and application for equipment and materials.

Siting and Design Considerations

Many of the problems associated with contamination of local waterways stem from the improper storage of deicing materials (Koppelman et al., 1984). Salts are very soluble when they come into contact with storm water. They can migrate into ground water used for public water supplies and also contaminate surface waters.

More information about road deicing materials can be found at the American Association of State Highway and Transportation Officials web page at *www.transportation.org/aashto/home.nsf/FrontPage*. **Limitations**

Road salt is the least expensive material for deicing operations; however, once the full social costs are taken into account, alternative products and better management and application of salts become increasingly attractive options.

Maintenance Considerations

Covering stored road salts may be costly; however, the benefits are greater than the perceived costs. Storing road salts correctly prevents the salt from lumping together, which makes it easier to load and apply. In addition, covering salt storage piles reduces salt loss from storm water runoff and potential contamination to streams, aquifers, and estuarine areas. Salt storage piles should be located outside the 100-year floodplain for further protection against surface water contamination.

During road salt application, certain best management practices can produce significant environmental benefits. The amount of road salt applied should be regulated to prevent oversalting of motorways and increasing runoff concentrations. The amount of salt applied should be varied to reflect site-specific characteristics, such as road width and design, traffic concentration, and proximity to surface waters. Calibration devices for spreaders in trucks aid maintenance workers in the proper application of road salts. Alternative materials, such as sand or gravel, should be used in especially sensitive areas

SPILL RESPONSE AND PREVENTION

Description

Spill response and prevention plans should clearly state measures to stop the source of a spill, contain the spill, clean up the spill, dispose of contaminated materials, and train personnel to prevent and control future spills.

Applicability

Spill prevention and control plans are applicable to construction sites where hazardous wastes are stored or used. Hazardous wastes include pesticides, paints, cleaners, petroleum products, fertilizers, and solvents.

Siting and Design Considerations

Identify potential spill or source areas, such as loading and unloading, storage, and processing areas, places where dust or particulate matter is generated, and areas designated for waste disposal. Also, spill potential should be evaluated for stationary facilities, including manufacturing areas, warehouses, service stations, parking lots, and access roads.

Material handling procedures and storage requirements should be defined and actions taken to reduce spill potential and impacts on storm water quality. This can be achieved by

- Recycling, reclaiming, or reusing process materials, thereby reducing the amount of process materials that are brought into the facility
- Installing leak detection devices, overflow controls, and diversion berms
- Disconnecting any drains from processing areas that lead to the storm sewer
- Performing preventative maintenance on storm tanks, valves, pumps, pipes, and other equipment
- Using material transfer procedures or filling procedures for tanks and other equipment that minimize spills
- Substituting less- or non-toxic materials for toxic materials.

Provide documentation of spill response equipment and procedures to be used, ensuring that procedures are clear and concise. Give step-by-step instructions for the response to spills at a particular facility. This spill response plan can be presented as a procedural handbook or a sign.

The spill response plan should

- Identify individuals responsible for implementing the plan
- Define safety measures to be taken with each kind of waste
- Specify how to notify appropriate authorities, such as police and fire departments, hospitals, or publicly-owned treatment works for assistance
- State procedures for containing, diverting, isolating, and cleaning up the spill
- Describe spill response equipment to be used, including safety and cleanup equipment.

Education is essential for reducing spills. By informing people of actions they can take to reduce spill potential, spills will be reduced and/or prevented. Some municipalities have set up 1-800 numbers for citizens to call in the event of spills. This is helpful for ensuring that spills are cleaned up in a safe, proper, and timely manner.

Limitations

A spill prevention and control plan must be well planned and clearly defined so that the likelihood of accidental spills can be reduced and any spills that do occur can be dealt with quickly and effectively. Training might be necessary to ensure that all workers are knowledgeable enough to follow procedures. Equipment and materials for cleanup must be readily accessible and clearly marked for workers to be able to follow procedures.

Maintenance Considerations

Update the spill prevention and control plan to accommodate any changes in the site or procedures. Regularly inspect areas where spills might occur to ensure that procedures are posted and cleanup equipment is readily available.

Effectiveness
A spill prevention and control plan can be highly effective at reducing the risk of surface and ground water contamination. However, the plan's effectiveness is enhanced by worker training, availability of materials and equipment for cleanup, and extra time spent by management to ensure that procedures are followed.

USED OIL RECYCLING

Description
Used motor oil is a hazardous waste because it contains heavy metals picked up from the engine during use. Fortunately, it is recyclable because it becomes dirty from use, rather than actually wearing out. However, as motor oil is toxic to humans, wildlife, and plants, it should be disposed of at a local recycling or disposal facility. Before disposal, used motor oil should be stored in a plastic or metal container with a secure lid, rather than dumped in a landfill or down the drain. Containers that previously stored household chemicals, such as bleach, gasoline, paint, or solvents should not be used. Used motor oil should also never be mixed with other substances such as antifreeze, pesticides, or paint stripper.

Used motor oil is recycled in a number of different ways. It can be *reprocessed* into fuel for heating and cooling homes. Reprocessing is the most common method of recycling used oil in the United States. Approximately 750 million gallons of used oil are reprocessed every year and marketed to asphalt plants, steel mills, boilers, pulp and paper mills, cement/lime kilns, and a number of other places. Motor oil can also be burned in furnaces for heat or in power plants to generate electricity for homes, businesses, or schools. It can also be blended for marine fuels, mixed with asphalts for paving, or be used in industrial burners. Used motor oil can also be used in specially designed municipal garages, space heaters, and automotive bays. Finally, used motor oil can be re-refined into lubricating oils that meet the same standards as virgin/new oil. All of these methods of recycling help to conserve valuable energy resources.

When establishing oil recycling programs, municipalities should provide the public with the proper informational resources. Programs should encourage the public to contact local service stations, municipal governments, the county government office, or the local environmental or health departments, if they are unsure where to safely dispose of their oil. The public can also call 1-800-RECYCLE or contact Earth's 911 at *www.1800cleanup.org/* for more information. Finally, state government contacts, who might be able to provide information about oil recycling, can be obtained by the public at *www.noraoil.com/Contact/contact.html*.

Municipalities also need to address oil filter recycling in their recycling programs. Programs should encourage the public to check with local collection facilities to determine whether oil filters are recycled locally. The Filter Manufacturers Council, which was established in 1971 to monitor regulatory and technological developments that affect the oil industry, can also be used as a resource for the public. The Council operates a hotline (1-800-99-FILTER) and a web site (*www.filtercouncil.org/*) to provide information about state regulations and companies that transport, recycle, and process used oil filters. If oil filters are not recycled locally, empty filters should be wrapped in newspaper and disposed of with regular household waste. Oil filters must always be drained of oil, whether recycling or disposing of the filter. The public should also check with trash collectors to determine if their state permits disposal of oil filters in landfills.

Applicability
Motorists that have their oil changed can be classified as a do-it-yourselfer or a do-it-for-me. Do-it-yourselfers change their own oil because they want to save money, they enjoy it, or they take pride in the quality of their own workmanship. According to a recent survey, more than 30 percent of motorists change their own oil. Between 43 and 62 million gallons of used oil were collected and recycled by do-it-yourselfers in 1997 (API, 2000). Therefore, it is important that do-it-yourselfers recycle their used oil. Do-it-for-mes have their oil changed at places such as service stations or quick lubes; they should be sure to check if their mechanic recycles motor oil.

To make recycling motor oil more convenient for the do-it-yourselfers, oil recycling programs should be located throughout all communities. Although oil recycling programs are appropriate in any community, urban areas are in particular need of programs, as more motor oil is used in these areas to maintain a larger number of vehicles. Therefore, oil recycling programs should more heavily target urban areas and provide a greater number of facilities for recycling oil in these areas.

Implementation

Oil recycling programs can be implemented easily throughout the country. Two types of programs currently in use are drop-off locations and curbside collection. Drop-off locations include service stations, recycling centers, auto parts retail stores, quick lubes, and landfills. These locations are effective because they are familiar, convenient, permanent, and well located. Additionally, sites that are permanent allow for effective publicity for recycling programs. Curbside collection programs allow consumers to put their oil out on the curb for collection, as they already do with their other recycling and trash. While this program is more convenient for the user, it requires a hauler to come and collect the oil. Oil recycling programs that use drop-off locations for collection are implemented by local governments, state governments, service stations, quick lubes, auto parts retailers, oil processors, or any combination of the above. Curbside collection programs are implemented by municipal or private waste haulers, municipal or private recycling haulers, or a combination of any of the above.

Local Recycling Programs. Many states, cities, and communities have developed their own recycling programs. For example, the California Integrated Waste Management Board sponsors a used oil recycling program that develops and promotes alternatives to illegal oil disposal. This is accomplished through a statewide network of collection opportunities and outreach efforts that publicize and encourage used oil recycling. The program provides useful information for the public, including collection locations, certification information, proposed regulations, used oil facts, and a number of other resources. More information about this program can be found at *www.ciwmb.ca.gov/usedoil/Default.htm*. Other cities with used oil programs are King County, Washington; Kansas City, Missouri; Clark County, Ohio; and New Carollton, Maryland. All of these programs can be used as models for other communities to develop their own programs.

National Recycling Programs. In 1991, the American Petroleum Institute (API) established a used oil collection and recycling program. This program works to educate the public about collecting and recycling used oil, making oil collection more convenient, and ensuring that this valuable resource is handled appropriately. Information about API's Used Motor Oil Program is available at *www.recycleoil.org*. API has also developed model legislation, based on Florida's program, to encourage collection and recycling of used oil. Florida's legislation specifically requires states to create a special fund to help cities and towns establish used oil collection facilities. Additionally, it emphasizes the importance of educating the public about oil recycling. Guidance for developing collection programs, in the form of API's model legislation as well as guidebooks and publications, can be found at *www.recycleoil.org/legislative.htm*.

Benefits

Recycling used motor oil is beneficial to the environment, the public health, and the economy. If oil is improperly disposed of in landfills, ditches, or waterways or dumped on the ground or down storm sewers, it can migrate into surface and ground water. It takes only one gallon of oil to contaminate one million gallons of drinking water (USEPA, 2000). This same oil can also seriously harm aquatic plants and animals. Submerged vegetation is especially affected by oil because the oil blocks sunlight from entering the water and hinders photosynthesis. As motor oil causes 40 percent of the pollution in America's waterways (Mississippi DEQ), water pollution could dramatically decrease if that same oil was recycled.

It is also beneficial to recycle motor oil because one gallon of re-refined oil produces 2.5 quarts of lubricating oil, while 42 gallons of crude oil are necessary to produce this same amount. It also takes three times as much energy used to refine crude oil to lubricating oil than it does to re-refine used motor oil. If the 180 million gallons of recoverable motor oil that are thrown away each year were recycled, this would produce enough energy to power 360,000 homes annually. Finally, if the 1.3 billion gallons of oil wasted each year by the United States were re-refined, it would save 1.3 million barrels of oil a day (Mississippi DEQ).

Recycling used motor oil is also beneficial in protecting public health. As oil circulates through a car's engine, it collects rust, dirt, metal particles, and a variety of contaminants. Engine heat can also break down oil additives, producing acids and a number of other substances. Exhaust gases and antifreeze can also leak into oil when the engine is in use. When any of these substances mix with oil, the toxicity of oil is greatly increased. Then, if oil is disposed of improperly and enters the water or air, public health can be seriously threatened.

Recycling used motor oil is also beneficial to the economy. Oil is a valuable resource that can be re-refined and reused in combustion engines. As oil is a non-renewable resource, it will become increasingly more difficult to find new reserves in the future. Therefore, recycling will provide time to develop alternative fuels and lessen dependence on foreign oil suppliers.

Limitations

One limitation to recycling oil is the possibility of contamination during collection. If oil is mixed with other substances or if storage containers have residues of other substances, this can contaminate oil and make it a hazardous waste. In these cases, collection facilities are responsible for disposing of this hazardous waste and abiding by appropriate rules. Another limitation is educating the public. While oil recycling programs can be effective, it is often difficult to effectively educate the public and convince them of the importance of recycling oil. This limitation can be addressed if municipalities include recycling information in utility bill inserts, newspaper ads, and mailings. A last limitation is that some might find it inconvenient to take their oil to a recycling facility. People may not have time to drive their oil to a facility or the facility may be difficult to find. When this happens, people are more likely to dispose of their oil improperly.

Effectiveness

According to a 1998 survey, 30 percent of motorists change their oil themselves. Of those people, 12 to 15 percent report that they improperly dispose of their oil. While most people claim that they put the oil in the trash, 3 to 5 percent say that they dispose of their oil in a storm drain system. Based on this survey, more than half of do-it-yourselfers improperly dispose of used motor oil. A 1994 survey reports that of the 28 percent who are do-it yourselfers, 17 percent report improper disposal. These statistics can be improved through better advertisement of recycling facilities and by making recycling more convenient for the public.

MATERIALS MANAGEMENT

Description

Responsibly managing common chemicals, such as fertilizers, solvents, paints, cleaners, and automotive products, can significantly reduce polluted runoff (WEF and ASCE, 1998). Such products must be handled properly in all stages of their useful lives. Materials management entails the selection of the individual product, the correct use and storage of the product, and the responsible disposal of associated waste(s).

Applicability

In many cases, industries can implement simple housekeeping practices in order to manage materials more effectively. Proper management reduces the likelihood of accidental spills or releases of hazardous materials during storm events. In addition, health and safety conditions at the facility will improve.

Some simple practices for managing materials are improving maintenance of industrial machinery, establishing material storage and inventory controls, improving routine cleaning and inspection of facilities where materials are stored or processed, maintaining organized workplaces, and educating employees about the benefits of the above practices (USEPA, 1992).

Maintenance Considerations

Maintenance associated with materials management should be designed to minimize the amounts of materials used and the wastes generated by industrial processes. Procedures for operation and maintenance can easily be integrated into an industry's management plan. Simple processes, such as routine cleaning of work spaces, proper collection and disposal of wastes, maintenance of machinery, regular inspections of equipment and facilities, and training employees to respond to spills or leaks, have significant effects on reducing storm water runoff.

Another consideration is regular material inventories. Such inventories reduce the occurrence of overstocking hazardous materials, increase knowledge about what hazardous materials are present and how they are stored, and provide documentation of proper handling of hazardous materials. An inventory of hazardous materials present at a particular site consists of three major steps (USEPA, 1992):

- Identify all hazardous and nonhazardous substances present in a facility. This can be accomplished by reviewing all purchase orders for the facility and walking through the facility itself. Compile a list of all chemicals present in a facility and obtain a Material Safety Data Sheet (MSDS) for each one.
- Label all containers with the name of the chemical, unit number, expiration date, handling instructions, and health or environmental hazards. Much of this information will be found on the MSDS. Often, insufficient labeling leads to improper handling or disposal of hazardous substances.
- Make special note on the inventory of hazardous chemicals that require special handling, storage, or disposal.