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Municipal Wastewater Management Fact Sheets

Storm Water Best Management Practices

MUNICIPAL WASTEWATER MANAGEMENT
FACT SHEETS
STORM WATER BEST MANAGEMENT PRACTICES
EPA-832-F-93-013

Prepared by the Municipal Technology Branch
United States Environmental protection Agency
Office of Water, Washington, D.C.

INTRODUCTION

Storm water runoff is part of a natural hydrologic process. However, human activities, particularly urbanization, can alter drainage patterns and add pollution to the rain water and snow melt that runs off the earth's surface and enters our Nation's rivers, streams, lakes, and coastal waters. A number of recent studies have shown that storm water runoff is a major source of water pollution as indicated by a decline in fish population and diversity, beach closings or restrictions on swimming and other water sports, bans on consumption of fish and shellfish and other public health concerns. These conditions limit our ability to enjoy many of the benefits that our Nation's waters provide.

In response to this problem, the States and many municipalities have been taking the initiative to manage storm water more effectively. In acknowledgement of these storm water management concerns, the U.S. Environmental Protection Agency (EPA) has undertaken a wide variety of activities, including providing technical assistance to States and municipalities to help them improve their storm water management programs.

This document contains fact sheets on storm water best management practices (BMPs). These fact sheets represent two types of BMPs: pollution prevention and treatment. Pollution prevention BMPs include both source controls and administrative practices. However, many are not stand alone BMPs, but are most effective when combined with other BMPs in a comprehensive storm water management plan. These BMPs are suitable for both municipal and industrial applications and can be used to supplement other EPA guidance documents such as **Storm Water Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices (EPA 832-R-92-006)** and **Storm Water Management for Construction Activities: Developing Pollution Prevention Plans and Best Management Practices (EPA 832-R-92-005)** as well as other State or local guidance.

In order to better serve our customers and identify additional information needs, a short questionnaire is included at the end of this document. Please take a few minutes to tell us if this document was helpful in meeting your needs and what other needs you have concerning storm water management. Responses can be mailed to the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC, 20460 or faxed to (202) 260-0116.

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PREFACE

This document is part of a series of municipal wastewater management fact sheets. These fact sheets are intended to serve a wide audience including: the consulting engineer who is looking for basic technical information on technologies; the municipal engineer who must understand these technologies well enough to evaluate the assets and limitations; the municipal official who must sell the technologies as part of a comprehensive pollution prevention program; the state regulator who must approve the technologies used to meet permit requirements; and ultimately the citizen who must understand the importance of preventing pollution of the Nation's waters.

The material presented is guidance for general information only. This information should not be used without first obtaining competent advice with respect to its suitability to any general or specific application. References made in this document to any specific method, product or process does not constitute or imply an endorsement, recommendation or warranty by the U.S. Environmental Protection Agency.

Municipal Wastewater Management Fact Sheets are divided into several sets: Wet Weather Flow Management Practices; Innovative and Alternative Technologies; Biosolids Technologies and Practices; Wet Weather Technologies; Water Conservation, etc. Each set is published separately starting with Storm Water Best Management Practices, September, 1993. Updates to this set of fact sheets and development of additional sets is dependent upon continued resources being available.

EPA MTB
Office of Wastewater Enforcement & Compliance
MUNICIPAL TECHNOLOGY BRANCH

STORM WATER BMP: CATCH BASIN CLEANING

DESCRIPTION

Catch basins are chambers or sumps, usually built at the curb line, which allow surface water runoff to enter the storm water conveyance system. Many catch basins have a low area below the invert of the outlet pipe intended to retain sediment. By trapping coarse sediment, the catch basin prevents solids from clogging the storm sewer and being washed into receiving waters. Catch basins must be cleaned out periodically to maintain their sediment trapping ability. The removal of sediment, decaying debris, and highly polluted water from catch basins has aesthetic and water quality benefits, including reducing foul odors, reducing suspended solids, and reducing the load of oxygen-demanding substances that reach surface water.

CURRENT STATUS

Catch basin cleaning is an easily implemented but often overlooked Best Management Practice. Frequently, the cleaning procedures deal with removal of debris from grate openings but do not extend down into the catch basin itself.

APPLICATIONS

Catch basin cleaning is applicable to any facility that has an on-site storm sewer system which includes catch basins and manholes.

LIMITATIONS

Limitations associated with cleaning catch basins include:

- Catch basin debris usually contains appreciable amounts of water and offensive organic material which must be properly disposed of.
- Catch basins may be difficult to clean in areas with poor accessibility and in areas with traffic congestion and parking problems.
- Cleaning is difficult during the winter when snow and ice are present.

PERFORMANCE

It is not possible, based on current data, to quantify the water quality benefits to receiving waters of catch basin cleaning. The rate at which catch basins fill with debris, as well as the total amount of material which can be removed by different frequencies of cleaning, are highly variable and cannot be readily predicted. Past studies have estimated that typical catch basins retain up to 57 percent of coarse solids and 17 percent of equivalent biological oxygen demand (BOD).

MAINTENANCE

A catch basin should be cleaned if the depth of deposits are equal to or greater than one-third the depth from the basin bottom to the invert of the lowest pipe or opening into or out of the basin. Catch basins should be, at a minimum, inspected annually. If a catch basin is found during the annual inspection to significantly exceed the one-third depth standard, it should be inspected and cleaned on a more frequent basis. If woody debris or trash is likely to accumulate in a catch basin, it should, at a minimum, be inspected and cleaned, if necessary, on a monthly basis.

In addition, data collected as part of a Nationwide Urban Runoff Program (NURP) project in Castro Valley Creek, California indicated that a typical catch basin, which were cleaned once per year or once every other year contained approximately 60 pounds of material each.

Catch basins can be cleaned either manually or by specially designed equipment. These include bucket loaders and vacuum pumps. Material removed from catch basins is usually disposed of in landfills.

COSTS

Catch basin cleaning costs will vary depending upon the method used, required cleaning frequency, amount of debris removed, and debris disposal costs. Cleaning costs for catch basins were estimated in three NURP program studies (Midwest Research Institute, 1982). These estimates are summarized in Table 1 below.

TABLE 1. CLEANING COST PER CATCH BASIN

LOCATION	METHOD	COST
Castro Valley, CA	Vacuum attached to street sweeper	$7.70
Salt Lake County, UT,	Vacuum attached to street sweeper	$10.30
Winston-Salem, NC	Vacuum attached to street sweeper	$6.30

SOURCE: Reference 1.

In communities equipped with vacuum street sweepers, a cleaning cost of $8 per basin cleaned is recommended for budgetary purposes (Southeastern Wisconsin Regional Planning Commission, 1991). Cleaning catch basins manually costs approximately twice as much as cleaning the basins with a vacuum attached to a sweeper. Therefore, a cost estimate of $16 per catch basin cleaned may be used for manual cleaning. It should be noted that costs vary depending on local market conditions.

ENVIRONMENTAL IMPACTS

Sediment and debris removed from catch basins must be disposed of in a proper manner to avoid negative environmental impacts.

REFERENCES

1. Midwest Research Institute, Collection of Economic Data from Nationwide Urban Runoff Program Projects–Final Report. Report to U.S. Environmental Protection Agency, March, 1982.

2. Minnesota Pollution Control Agency, Protecting Water Quality in Urban Areas, 1989.

3. Southeastern Wisconsin Regional Planning Commission, Cost of Urban Nonpoint Source Water Pollution Control Measures, Technical Report No. 31, June, 1991.

4. U.S. EPA, Results of the Nationwide Urban Runoff Program, December, 1983.

5. U.S. EPA, Catch Basin Technology Overview and Assessment, May, 1977.

6. Washington State Department of Ecology, Storm Water Management Manual for Puget Sound, February, 1992.

STORM WATER BMP: COVERINGS

MTB
Office of Wastewater Enforcement & Compliance
MUNICIPAL TECHNOLOGY BRANCH

DESCRIPTION

A simple yet effective Best Management Practice (BMP) is covering. Covering is the partial or total enclosure of raw materials, byproducts, finished products, containers, equipment, process operations, and material storage areas which, when exposed to rain and/or runoff, could contaminate stormwater. Tarpaulins, plastic sheeting, roofs, buildings, and other enclosures are examples of temporary or permanent covering that are effective in preventing stormwater contamination. The most prominent advantage of covering is that it is inexpensive in comparison to other BMPs.

CURRENT STATUS

A review of numerous NPDES group applications indicates that covering is a commonly implemented BMP. As more facilities identify potential sources of stormwater contamination, the use of coverings will increase significantly due to its effectiveness from a performance and cost perspective.

APPLICATIONS

Covering is appropriate for loading/unloading areas, raw material, byproduct and final product outdoor storage areas, fueling and vehicle maintenance areas, and other high risk areas.

LIMITATIONS

Limitations associated with covering as a BMP include:

- Temporary methods such as plastic sheeting can become torn or ripped, exposing the contaminant to precipitation and/or stormwater runoff.
- Costs may prohibit the building of complete enclosures.
- May pose health or safety problems for enclosures built over certain materials or activities.
- Requires frequent inspection.
- A structure with only a roof may not keep out all precipitation.

PERFORMANCE

It is difficult, based on data currently available, to quantify the mitigation of runoff contamination when covering is used. However, significant runoff water quality benefits are expected by simply reducing the contact between potential contaminants and precipitation or stormwater runoff. One source has estimated that 80 percent of the environmental damage from de-icing chemicals is caused by inadequate storage facilities.

DESIGN CRITERIA

Evaluate the integrity and durability of the covering, as well as its compatibility with the material or activity being enclosed. When designing an enclosure, one should consider materials access, handling and transfer. Materials that pose environmental and/or safety dangers because they are radioactive, pathogenic, flammable, explosive, or reactive require special ventilation and temperature considerations.

Covering alone may not protect exposed materials from stormwater contact. Placing material on an elevated impermeable surface or building curbing around the outside of the materials may be required to prevent contact with stormwater runoff from adjacent areas.

Practicing proper materials management within an enclosure or underneath a covered area is essential. For example, floor drainage within an enclosure should be properly designed and connected to a sanitary sewer. The local publicly owned treatment works should be consulted to determine if there are any pretreatment requirements, restrictions, or compatibility problems prior to discharge.

MAINTENANCE

Maintenance involves frequent inspection of the covering for rips, holes, and general wear. Inspecting coverings should be part of an overall preventive maintenance program.

COSTS

Covering costs vary in proportion to the degree of protection desired, and the required lifespan. The most inexpensive covering is plastic sheeting, but it is not suitable where a high degree of protection is desired for a long period. An enclosed building is the most expensive type of covering when materials for the structure, lighting, and ventilation are considered, but it offers the highest degree of protection for the longest period.

ENVIRONMENTAL IMPACTS

The impact from a covered area depends on the degree of complexity in the covering design. A simple plastic sheeting can possibly have a stormwater diversion, and allow for disposal of uncontaminated water to a storm sewer. A structure with a permanent roof may be less effective, if the material inside is not sufficiently protected from contact with runoff. An enclosed structure may need to have internal drainage. If this is the case, it must not be connected to the storm sewer, and may not be suitable connection to a sanitary sewer, if the stored material is considered hazardous. The internal drains would then need to be connected to some suitable containment area for later disposal.

REFERENCES

1. Minnesota Pollution Control Agency, Protecting the Water Quality in Urban Areas, 1989.

2. U.S. EPA, Stormwater Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices, Pre-print, July 1992.

3. Washington State Department of Ecology, Stormwater Management Manual for Puget Sound, February 1992.

STORM WATER BMP: DUST CONTROL

DESCRIPTION

Dust controls are methods that prevent pollutants from entering stormwater discharges by reducing the surface and air transport of dust caused by industrial or construction activities. Control measures can prevent dust from spreading into areas of a facility where runoff may eventually transport the material to a storm sewer collection system or directly to a receiving waterbody.

Dust control for industrial activities normally involves mechanical systems designed to reduce dust emissions from in-plant, processing activities, and/or materials handling. These may include hoods, cyclone collectors, bag-type collectors, filters, negative pressure systems, or mechanical sweepers.

Dust control measures for construction activities include windbreaks, minimization of soil, spray-on adhesives, tillage, chemical treatment, and water spraying.

COMMON MODIFICATIONS

There are a number of temporary alternatives for dust control. However, another consideration is to eliminate the need for temporary dust control completely by permanent modification of the site. This could include such measures as covering exposed areas with vegetation, stone, or concrete.

APPLICATIONS

Dust control measures may be applied to any site where dust generation can cause damage to the site or adjacent properties. However, application of dust controls is especially critical in arid areas where reduced rainfall levels expose soil particles for transport by air and runoff into water bodies. Dust control measures should also be applied to any industrial activity where dust poses a threat of contamination to water bodies.

LIMITATIONS

Primary limitations of dust control include :

- Some temporary dust controls must be reapplied or replenished on a regular basis.
- Some controls are expensive (e.g., chemical treatment) and may be ineffective under certain conditions.
- Some controls may cause an increase in the amount of mud being tracked off-site.
- Typical windbreaks are not as effective as chemical treatment or mulching and seeding, and may require land space that might not be available at all locations.
- Industrial dust control is typically labor and equipment intensive and may not be effective for all sources of pollution (e.g. street sweepers).
- More elaborate industrial dust control systems require trained personnel to operate them, an require the implementation of a preventive maintenance and repair program to ensure operational readiness.

PERFORMANCE

The decision on which dust control measures to implement must take into consideration the performance objectives required for a particular site. Some examples of performance objectives include:

- Prevent wind and water-based erosion of disturbed areas
- A reduction of employee respiratory problems.
- Rapid implementation at low cost and effort.
- Little or no impact on the environment.
- Permanent control of the dust problem.

Based on the objectives simply sweeping the impervious areas for larger particles on a routine basis may provide an efficient and reliable method of dust control that can be quickly implemented. Other controls might include vegetative windbreaks which would provide a much more permanent and environmentally safe alternative to chemical use.

DESIGN CRITERIA

The main goals of the dust control project design is to limit dust generation and reduce the amount of soil or dust particulate exposed. However this must also take into consideration the performance objectives established for the particular project. Additionally, some project sites may require solutions to both industrial and dust control problems. Realistically it may not be practical or possible to develop a design that meets all of the project goals and objectives at one time. Therefore it may be more appropriate to develop a phased design approach that utilizes a combination of temporary, permanent, or mechanical measures for dust control.

TEMPORARY MEASURERS

- Vegetative Coverings: Temporary seeding and mulching may be applied to cover bare soil and prevent wind erosion.
- Adhesives: Use spray-on adhesives according to Table 1 below. It is recommended using these adhesives only if other methods cannot be used as many of them are difficult to work with and form fairly impenetrable surfaces.
- Wetting: This is generally done as an emergency treatment. The site is sprinkled with water until the surface is wet and repeated as necessary. If this method is to be employed, it is recommended that a temporary gravel rock entrance be created to prevent carry-out of mud onto local streets.
- Tillage: This practice roughens the soil and brings clods to the surface. It is an emergency measure that should be used before wind erosion starts. Plowing should begin on the windward side of the site using chisel-type plows spaced about 12 inches apart, spring-tooth harrows, or similar plows.
- Barriers: Solid board fences, snow fences, burlap fences, crate walls, bales of hay, and similar material can be used to control air currents and soil blowing. Barriers placed at right angles to prevailing currents at intervals of about 15 times the barrier height are effective in controlling wind erosion.

- Calcium Chloride: This material is applied at a rate that will keep the surface moist. Pretreatment may be necessary due to varying site and climatic conditions.

TABLE 1: DESIGN OF ADHESIVE MEASURERS

Type of Emulsion	Water Dilution	Nozzle Type	Application Rate (gallons per acre)
Anionic Asphalt	7 to 1	Coarse	1,200
Latex	12.5 to 1	Fine	235
Resin and Water	4 to 1	Fine	300

SOURCE: Reference 1.

PERMANENT MEASURERS

- Permanent Vegetation: Seeding and sodding should be done to permanently stabilize exposed areas against wind erosion. It is recommended that existing trees and large shrubs remain in place to the greatest extent possible during site grading processes.

- Stone: The purpose of this method is to place coarse gravel or crushed stone over highly erodible soils.

- Topsoiling: This method is recommended when permanent vegetation cannot be established on a site. Topsoiling is a process in which less erosive soil material is placed on top of highly erodible soils.

- Cyclone Collectors. Cyclone collectors separate dry dust and particulate pollutants in the air by centrifugal force.

- Bag Collectors/Fabric Filters. Bag collectors or fabric filters remove dust by filtration. Storage of collected dust should be carefully considered so that it does not become a source of fugitive dust.

- Negative Pressure Systems. These systems minimize the release of dust from an operation by maintaining a small negative pressure or suction to confine the dust to a particular operation.

- Water Spraying. This temporary mechanical method confines and settles the dust from the air by dust and water particle adhesion. Water is sprayed through nozzles over the problem area.

- Street Sweepers. Two kinds of street sweepers are common in mechanical dust collection systems. The brush system has proven to be an efficient method at an industrial facility generating dust on a daily basis. It has proven to be extremely dependable and picks up the majority of the dust. Vacuum sweepers are presumed to be more efficient because the pollutants typically associated with contaminating stormwater are the smaller particles which may be left behind by a brush street sweeper. However, no performance data are as yet available to verify that vacuum sweepers are more efficient than brush sweepers.

MAINTENANCE

Typically, all dust control measures require periodic and diligent maintenance. For example, mechanical equipment should be operated according to the manufacturers recommendations and inspected regularly as part of an industrial site's preventive maintenance program. Temporary dust control measures, such as chemical spraying, watering, etc. require periodic renewal. Permanent solutions such as vegetation, wind barriers, impervious services also require upkeep and maintenance in order to remain effective.

COSTS

The costs associated with dust control measures are generally lower for vegetative and barrier methods, and increases significantly for chemical and mechanical treatments. For example, an industrial facility purchased a mechanical brush sweeper for approximately $35,000.

ENVIRONMENTAL IMPACTS

There are several negative environment impacts which are related to the dust control BMPs. These include :

- If over-application of a chemical treatment to control dust occurs, excess chemicals could be exposed to both wind and rain erosion with potential for both surface and groundwater contamination.
- Oil should never be used to control dust because of the high potential for polluting stormwater discharges.
- When using mechanical measures such as street sweepers, disposal is a major problem and could involve parameter testing of dust particulate. RCRA regulations may be applicable to this situation.

REFERENCES

1. City of Eagan, Minnesota, Erosion Control Manual, 1984
2. Hennepin County, Minnesota, Erosion and Sediment Control Manual, 1989.
3. Minnesota Board of Water and Soil Resources, Minnesota Construction Site Erosion and Sediment Control Planning Handbook, November 1987.
4. U.S. EPA, NPDES Best Management Practices Guidance Document, December 1979.
5. U.S. EPA, Stormwater Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices, September 1992.

This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC 20460.

STORM WATER BMP: EMPLOYEE TRAINING

MTB
Office of Wastewater Enforcement & Compliance
MUNICIPAL TECHNOLOGY BRANCH

DESCRIPTION

In-house training programs are designed and implemented to teach employees about stormwater management, potential sources of contaminants, and Best Management Practices (BMPs). Employee training programs should instill all personnel with a thorough understanding of their Stormwater Pollution Prevention Plan (SWPPP). This includes identification of BMP's, processes and materials they are working with, safety hazards, practices for preventing discharges, and procedures for responding quickly and properly to toxic and hazardous material incidents.

CURRENT STATUS

Typically, most industrial facilities have an employee training program. Usually these address such areas as health and safety training, or fire protection. The effort required to modify these programs to include discussion of stormwater management and BMP implementations should be reasonable.

APPLICATIONS

Employee training program implementation can be achieved through posters and bulletin boards designed to raise awareness of stormwater management, potential contaminant sources, and prevention of surface water runoff contamination. Field training programs where employees are shown areas of potential stormwater contamination and associated pollutants, followed by a discussion of site-specific BMPs by trained personnel, would also be beneficial for implementing the program.

LIMITATIONS

Limitations of an employee training program include:

- Lack of employee motivation
- Lack of incentive to become involved in BMP implementation
- Lack of commitment from senior management

PERFORMANCE

Quantitative performance will vary between facilities because performance is dependent on employee participation and commitment from senior management to reduce point and nonpoint sources of pollution. Employee training programs that teach identification of potential sources of contaminants, are highly recommended for implementation at all facilities. Support of these programs should given the highest priority, by senior management.

DESIGN CRITERIA

Specific design criteria for implementing an employee training program include:

- Meetings should be held at intervals frequent enough to ensure adequate understanding of SWPPP goals and objectives.
- A strong commitment by, and periodic input from, senior management.
- Transmission of knowledge from past spill causes and solutions to prevent future spills.
- Making employees aware of internal reporting procedures relative to BMP monitoring and spill reporting procedures.
- Operating manuals and standard procedures.
- Implementation of spill drills to minimize potential contamination of stormwater runoff from toxic pollutants.

MAINTENANCE

An employee training program should be an on-going yearly process. There should be, at a minimum, annual meetings to discuss SWPPPs.. These meetings could be held in conjunction with other training programs. Figure 1 below illustrates a sample employee training tracking worksheet.

EMPLOYEE TRAINING

Worksheet
Completed by: ____________
Title: ____________
Date: ____________

Instructions: Describe the employee training program for your facility below. The program should, at a minimum, address spill prevention and response, good housekeeping, and material management practices. Provide a schedule for the training program and list the employees who attend training sessions.

Training Topics	Brief Description of Training Program/Materials (e.g., film, newsletter course)	Schedule for Training (list dates)	Attendees
Spill Prevention and Response			
Good Housekeeping			
Material Management Practices			
Other Topics			

SOURCE: Reference 2.

FIGURE 1: SAMPLE WORKSHEET FOR TRACKING EMPLOYEE TRAINING

COSTS

Costs for implementing an employee training program are highly variable. It is anticipated that most stormwater training program costs will be directly related to labor and associated overhead costs. however, the example shown in Table 1 below can be used to estimate what the annual costs might be for an in-house training program at your facility. Figure 2 can be used as a worksheet to calculate the estimated cost for an employee training program.

TABLE 1: EXAMPLE OF ANNUAL EMPLOYEE TRAINING COSTS

Title	Quantity		Avg. Hourly Rate ($)		Overhead* Multiplier		Estimated Yearly Hours on SW Training		Est. Annual Cost ($)
Stormwater Engineer	1	x	15	x	2.0	x	20	=	600
Plant Management	5	x	20	x	2.0	x	10	=	2,000
Plant Employees	100	x	10	x	2.0	x	5	=	10,000
			TOTAL ESTIMATED ANNUAL COST						$12,600

Note: Defined as a multiplier (typically ranging between 1 and 3) that takes into account those costs associated with payroll expenses, building expenses, etc.

SOURCE: EPA

Title	Quantity		Avg. Hourly Rate ($)		Overhead Multiplier		Estimated Yearly Hours on SW Training		Est. Annual Cost ($)	
______	______	x	______	x	______	x	______	=	______	(A)
______	______	x	______	x	______	x	______	=	______	(B)
______	______	x	______	x	______	x	______	=	______	(C)
______	______	x	______	x	______	x	______	=	______	(D)
			TOTAL ESTIMATED ANNUAL COST (Sum of A+B+C+D)						______	

SOURCE: Reference 2

FIGURE 2: SAMPLE ANNUAL TRAINING COST WORKSHEET

REFERENCES

1. U.S. EPA, NPDES BMP Guidance Document, December, 1979.

2. U.S. EPA, Stormwater Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices, September, 1992.

This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC, 20460.

STORM WATER BMP: FLOW DIVERSION

MTB
Office of Wastewater Enforcement & Compliance
MUNICIPAL TECHNOLOGY BRANCH

DESCRIPTION

Structures which collect and divert runoff (such as gutters, drains, sewers, dikes, berms, swales, and graded pavement), are used in two ways to prevent the contamination of storm water and receiving water bodies. First, flow diversion structures may be used to channel storm water away from industrial areas so that storm water does not mix with on site pollutants. Second, they may also be used to carry contaminated runoff directly to a treatment facility.

Storm water conveyance systems can be constructed from many different materials, including concrete, clay tiles, asphalt, plastics, metals, rip-rap, and compacted soils covered with vegetation. The type of material used depends upon the design criteria used for conveyance of storm water runoff. These conveyances can be temporary or permanent.

Some advantages of storm water conveyance systems used for flow diversion purposes are:

- Direct storm water flows around industrial sites.
- Prevent temporary flooding of industrial site.
- Require low maintenance.
- Provide erosion-resistant conveyance of storm water runoff.
- Can typically be installed at any time.
- Provide long-term control of storm water flows.

COMMON MODIFICATIONS

Flow diversion structures can be modified by incorporating them with other pollution control best management practices. For example, diverted flow can be fed into an infiltration drain field system, diverted to an infiltration basin, diverted to a constructed wetland treatment facility, or diverted to an onsite treatment facility for discharge under the NPDES program. Another common modification is to construct a temporary flow diversion to determine its effectiveness. If the diversion structure is proven effective, it could then be converted to a permanent structure.

APPLICATIONS

Storm water diversions work well at most industrial sites. Storm water can be directed away from industrial areas by collecting it in a channel or drain system. Diversions can be used to collect storm water from the site and direct it down slope where it can be kept separate from runoff that has not been in contact with those areas. When potentially contaminated storm water is collected in a conveyance system, it can be directed to a treatment facility.

A good example of the utilization of a diversion structure is The Isle La Plume Wastewater Treatment Plant in La Crosse, WI The area immediately surrounding the facility has been regraded so that storm water runoff can be directed into the process tanks where it is treated right along with other wastewater. Figure 1 below illustrates this storm water runoff control method.

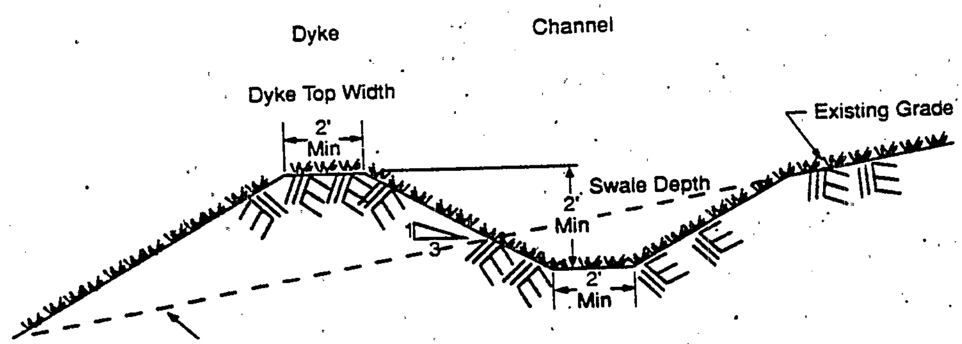
PERFORMANCE

Properly designed storm water diversion systems are very effective in preventing storm water from being contaminated or in routing contaminated flows to a proper treatment facility. For example, at the Denver Stapleton International Airport, flow diversion techniques intercept 99 percent of the glycol used and prevent its introduction to Sand Creek, the local receiving waterbody. At the La Crosse, WI Wastewater Treatment Plant, it is estimated that approximately one-third of the storm water runoff from the facility is diverted into their treatment process.

DESIGN CRITERIA

Planning for flow diversion structures should consider the typical volume and rate of storm water runoff present. Also, the patterns of storm water drainage should be considered so that the channels may be located to efficiently collect and divert the flow. When deciding on the type of material for the conveyance structure, consider the resistance of the material to erosion, its durability and compatibility with any pollutants it may carry.

Diversion systems are most easily installed during facility construction. Existing grades should be used to limit costs. Positive grades should be provided to allow for continued movement of runoff through the conveyance system. (Note: care must be exercised to limit velocities which could potentially increase erosion.) A typical diversion swale is shown in Figure 2 Below.



SOURCE: Reference 3.

FIGURE 2: TYPICAL DIVERSION SWALE DETAILS

MAINTENANCE

A maintenance program should be established to ensure proper functioning of the system. Storm water diversion systems should be inspected to remove debris within 24 hours after a significant rainfall event since heavy storms may clog or damage them. Flow diversion structures should also be inspected on an annual basis to ensure that they meet their hydraulic design requirements for proper performance.

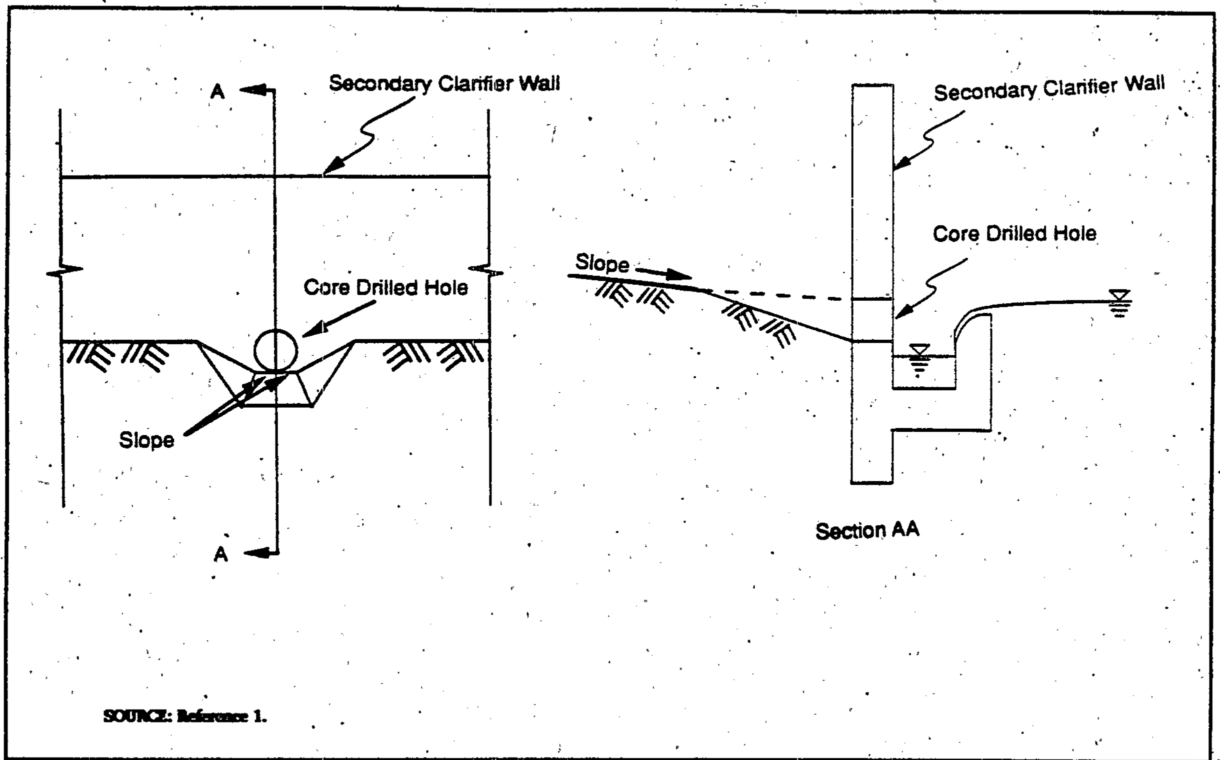


FIGURE 1: STORM WATER RUNOFF CONTROL MEASURERS

At the Denver Stapleton International Airport, the terminal area, aprons, and support facility areas (0.5 square miles), where activities resulting in storm water contamination are concentrated, are served by four individual large diameter storm sewers which collect storm water, snow melt, fuel spills, de-icing agents, and wash down flows. These storm sewers have hydraulic diversion structures in place which convey storm water flows to a 9 mgd detention basin. The basin contents are pumped to a sanitary sewer interceptor where it is then transferred to a local treatment facility.

Another concept being adapted into the new regional airport in Denver is based on centralized de-icing areas for use by all airlines. All de-icing area flows will be diverted to an on-site glycol recovery system or diverted to detention basins for discharge to the local treatment facility.

LIMITATIONS

Storm water flow diversion structure limitations include:

- Once flows are concentrated, they must be routed through stabilized structures, or treatment facilities in order to minimize erosion prior to discharging to receiving waters.
- May increase flow rates.
- May be impractical if there are space limitations.
- May not be economical especially for small facilities or after a site has been constructed.
- May require maintenance after heavy rains.

COSTS

Costs vary depending on the type of flow diversion structure used. For example, if vegetated swales are to be used for flow diversions, the Southeastern Wisconsin Regional Planning Commission (SEWRPC) reported that, in 1991, costs may vary between $8.50 to $50 per lineal foot, depending upon swale depth in feet and bottom width. Capital costs for the Stapleton International Airport flow diversion system, including basins, diversion structures in each of the four main storm sewers, and additional flow diversion modifications made by airport staff were $6 million in 1988. Clearly the cost will be determined by the scope of the project and design requirements.

ENVIRONMENTAL IMPACTS

Environmental impacts include:

- Erosion problems due to concentrated flows.
- Potential groundwater contamination if conveyance channels have high infiltration capacities.
- Undersized water treatment facilities may result in discharges that have not been adequately treated.

REFERENCES

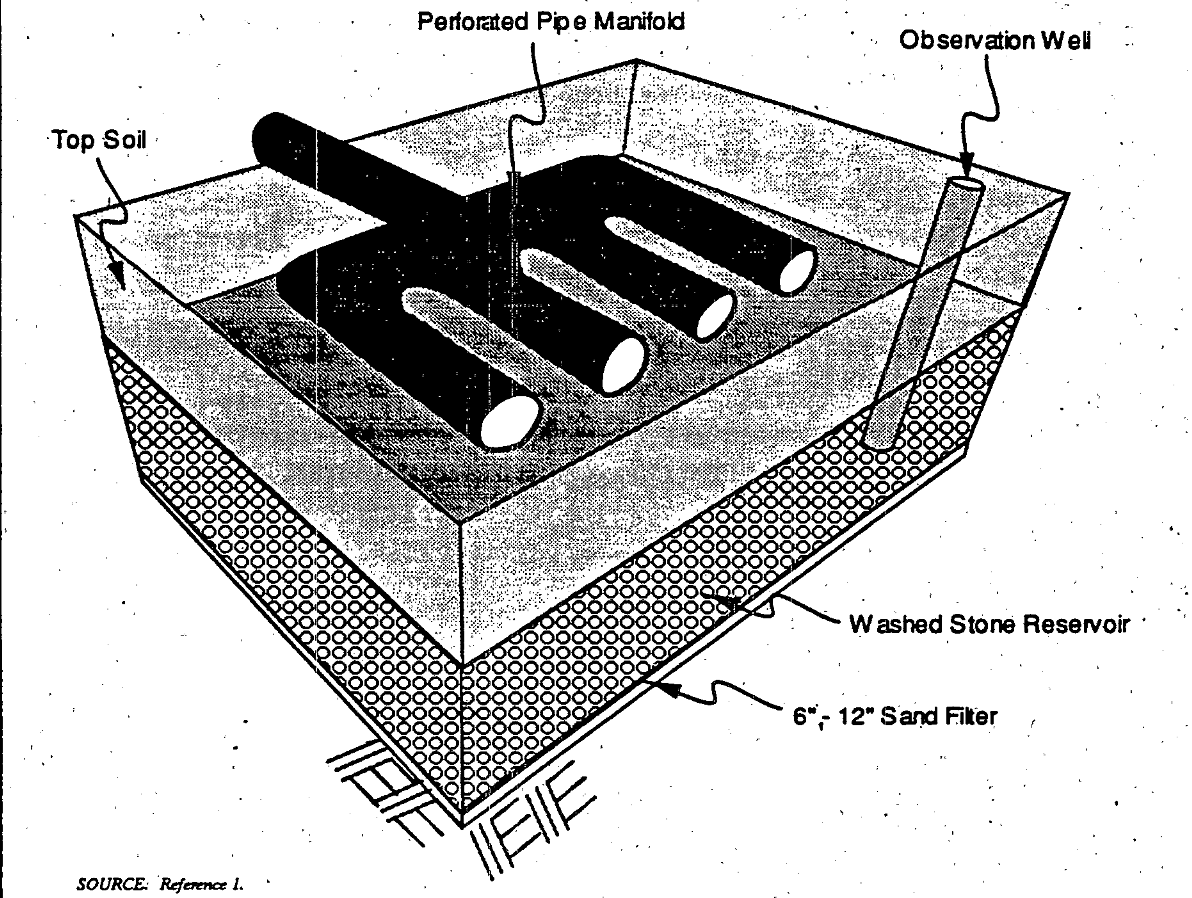
1. James M. Montgomery, Consulting Engineers, Inc., Site Visit Data, September 1992.
2. Minnesota Pollution Control Agency, Protecting Water Quality in Urban Areas, 1989.
3. Southeastern Wisconsin Regional Planning Commission, Costs of Urban Nonpoint Source Water Pollution Control Measures, Technical Report No. 31, June 1991.
4. U.S. EPA, NPDES BMP Guidance Document, June 1981.
5. U.S. EPA, Storm water Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices, September, 1992.
6. Washington State Department of Ecology, Storm water Management Manual for Puget Sound, February 1992.

This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC, 20460.

STORM WATER BMP: INFILTRATION DRAINFIELDS

DESCRIPTION

Infiltration drainfield structures are constructed to aid in stormwater runoff collection and are designed to allow stormwater to infiltrate into the subsoils. Runoff is diverted into a storm sewer system which passes through a pretreatment structure such as an oil and grit separator. The oil and grit chamber effectively removes coarse sediment, oils, and grease. Stormwater runoff continues through a manifold system into the infiltration drainfield. The manifold system consists of perforated pipe which distributes the runoff evenly throughout the infiltration drainfield. The runoff then percolates through the aggregate sand filter, the filter fabric and into the subsoils. A schematic of a typical system is illustrated in Figure 1 below.



SOURCE: Reference 1.

FIGURE 1: TYPICAL INFILTRATION DRAINFIELD SCHEMATIC

COMMON MODIFICATIONS

Common design modifications include the installation of porous pavement surrounded by a grass filter strip over the infiltration drainfield or insertion of an emergency overflow pipe in the oil and grit pretreatment chamber. The overflow pipe allows runoff volumes exceeding design capacities to discharge directly to a trunk storm sewer system. Infiltration drainfields are very similar to infiltration trenches and basins.

CURRENT STATUS

Currently there is little information on infiltration drainfields. However. in general the same principals that apply to infiltration basins and infiltration trenches will apply to design of infiltration drainfields. The Environmental Protection Agency is currently evaluating the following issues related to the design and operation of infiltration drainfields:

- Is the oil and grit separator the most effective pretreatment system to protect infiltration capacity?
- What is the pollutant removal capacity of infiltration drainfields with various pretreatment systems?
- Is the performance of infiltration drainfields better than infiltration basins and trenches during subfreezing weather and snow melt runoff conditions?
- What level of maintenance is required to ensure proper performance?

APPLICATIONS

Infiltration drainfields are most applicable on sites with a relatively small drainage area (less than 15 acres). They can be used to control runoff from parking lots, rooftops, impervious storage areas, or other land uses. Infiltration drainfields should not be used in locations that receive a large sediment load that could clog a pretreatment system, which in turn, would plug the infiltration drainfield and reduce its effectiveness.

Soils should have field-verified permeability rates of greater than 0.5 inches per hour and there should be a 4-foot minimum clearance between the bottom of the system and bedrock or the water table.

LIMITATIONS

The use of infiltration drainfields may be restricted in regions with colder climates, arid regions, regions with high wind erosion rates (increased windblown sediment loads), and areas where sole source potable aquifers could be contaminated. Some specific limitations of infiltration drainfields include:

- High maintenance when sediment loads to the drainfield are heavy.
- High costs of excavation, fill material, engineering design, and pretreatment systems.
- Short life span if not well maintained.
- Not suitable for use in regions with clay or silty soils.
- Not suitable for use in regions where groundwater is used locally for human consumption.

- Systems require sufficient time between storm events to allow the soil to dry out, or anaerobic conditions may develop in underlying soils which could clog the soil and reduce the capacity and performance of the system.

PERFORMANCE

The effectiveness of infiltration drainfields depends upon their design. When runoff enters the drainfield, many of the pollutants are prevented from entering surface water. However, any water that bypasses the pretreatment system and drainfield will not be treated. Pollutant removal mechanisms include absorption, straining, microbial decomposition in the soil below the drainfield, and trapping of sediment, grit, and oil in the pretreatment chamber.

Currently there is little monitoring data on the performance of infiltration drainfields. However, some monitoring data is available on porous pavements which incorporate many similar design criteria as infiltration drainfields. An estimate of porous pavement pollutant removal efficiencies range between 82 and 95 percent for sediment, 65 percent for total phosphorus, and 80 to 85 percent for total nitrogen.

Some key factors that increase performance and pollutant removal efficiencies include:

- Good housekeeping practices in the tributary drainage area.
- Sufficient drying time (24 hours) between storm events.
- Highly permeable soils and subsoils.
- Pretreatment system incorporated.
- Sufficient organic matter in subsoils.
- Proper maintenance.
- Use of a sand layer on top of a filter fabric at the bottom of the drainfield.

DESIGN CRITERIA

Infiltration drainfields, along with most other infiltration BMPs (infiltration basins, trenches, etc.) have demonstrated relatively short life spans in the past. Failures have generally been attributed to poor design, poor construction techniques, subsoils with low permeability and lack of adequate preventive maintenance. Some design factors which can significantly increase the performance and reduce the risk of failure of infiltration drainfields and other infiltration processes are shown in Table 1 below.

MAINTENANCE

Routine maintenance of infiltration drainfields is extremely important. The pretreatment grit chamber should be checked at least four times per year and after major storm events. Sediment should be cleaned out when the sediment depletes more than 10 percent of the available capacity. This can be done manually or by vacuum pump. Inlet and outlet pipes should also be inspected at this time.

The infiltration drainfield should contain an observation well. The purpose of the monitoring well is to provide information on how well this system is operating. It is recommended that the observation well be monitored daily after runoff-producing storm events. If the infiltration drainfield does not drain after three days, it usually means that the drainfield is clogged. Once the performance characteristics of the structure have been verified, the monitoring schedule can be reduced to a monthly or quarterly basis.

TABLE 1: INFILTRATION DRAINFIELD DESIGN CRITERIA

Design Criteria	Guidelines
Site Evaluation	• Take soil borings to a depth of at least 4 feet below bottom of stone reservoir to check for soil permeability, porosity, depth to seasonally high water table, and depth to bedrock. • Not recommended on slopes greater than 5 percent and best when slopes are as flat as possible. • Minimum infiltration rate 3 feet below bottom of stone reservoir: 0.5 inches per hour. • Minimum depth to bedrock and seasonally high water table: 4 feet. • Minimum setback from water supply wells: 100 feet. • Minimum setback from building foundations: 10 feet downgradient, 100 feet upgradient. • Drainage area should be less than 15 acres.
Design Storm Storage Volume	• Literature values suggest this parameter is highly variable and dependent upon regulatory requirements. One typically recommended storage volume is the stormwater runoff volume produced in the tributary watershed by the 6-month, 24-hour duration storm event.
Drainage Time for Design Storm	• Minimum: 12 hours. • Maximum: 72 hours. • Recommended: 24 hours.
Construction	• Excavate and grade with light equipment with tracks or oversized tires to prevent soil compaction. • As needed, divert stormwater runoff away from site before and during construction. • A typical infiltration cross-section consists of the following: 1) a stone reservoir consisting of coarse 1.5 to 3-inch diameter stone (washed); 2) 6 to 12-inch sand filter at the bottom of the drainfield; and 3) filter fabric.
Pretreatment	• Pretreatment is recommended to treat runoff from all contributing areas.
Dispersion Manifold	• A dispersion manifold should be placed in the upper portions of the infiltration drainfield. The purpose of this manifold is to evenly distribute stormwater runoff over the largest possible area. Two to four manifold extension pipes are recommended for most typical infiltration drainfield applications.

SOURCE: Reference 2.

COSTS

There is little information on the cost of infiltration drainfields. However, the construction costs for installing an infiltration drainfield that is 100 feet long, 50 feet wide, 8 feet deep and with 4 feet of cover can be estimated using the general information in Table 2 below.

TABLE 2: ESTIMATED COST FOR INSTALLING AN INFILTRATION DRAINFIELDS

Excavation Costs:	(2,220 cy) ($5.00/cy)	$11,100
Stone Fill	(1,296 cy) ($20.00/cy)	25,920
Sand Fill	(185 cy) ($10.00/cy)	1,850
Filter Fabric	Top and Bottom = 10,000 sf Sides = 1,600 + 800 = 2,400 sf Total = 12,400 sf + 10% = 13,640 sf (13,640 sf) (1 sy/9 sf) ($3.00/sy)	4,550
Perforated Manifold and Inlet Pipe	75' + 4(40') = 235' 40' (275) ($10.00/ft)	2,750
Observation Well	1 at $500 ea	500
Pretreatment Chamber	1 at $10,000	10,000
Miscellaneous (Backfilling, overflow pipe, sodding, etc.)		1,000
	SUBTOTAL	$57,670
Contingencies (Engineering, administration, permits, etc.) = 25%		14,420
	TOTAL	$72,090

Note: Unit prices will vary greatly depending upon local market conditions.

SOURCE: Reference 3.

ENVIRONMENTAL IMPACTS

One potential negative impact of infiltration drainfields is the risk of groundwater contamination. Studies to date do not indicate that this is a major risk. However, migration of nitrates and chlorides has been documented.

REFERENCES

1. Metropolitan Washington Council of Governments, Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs, 1987.

2. Minnesota Pollution Control Agency, Protecting Water Quality in Urban Areas, 1989.

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5. Washington State Department of Ecology, Stormwater Management Manual for the Puget Sound Basin, February 1992.

This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC, 20460.

STORM WATER BMP: INTERNAL REPORTING

DESCRIPTION

Internal reporting provides a framework for "chain-of-command" reporting of stormwater management issues. Typically, a facility develops a Stormwater Pollution Prevention Team (SWPPT) concept for implementing, maintaining, and revising the facility's Stormwater Pollution Prevention Plan (SWPPP). The purpose of identifying a SWPPT is to clarify the chain of responsibility for stormwater pollution prevention issues and provide a point of contact for personnel outside the facility who need to discuss the SWPPP.

CURRENT STATUS

The U.S. EPA first identified internal reporting as a Best Management Practice (BMP) in the late 1970s. Currently, internal reporting has evolved into development of an SWPPT for facilities implementing an SWPPP as part of their NPDES stormwater discharge permit. This SWPPT concept is a new and innovative part of the SWPPP.

IMPLEMENTATION

The key to implementing internal reporting as a BMP is to establish a qualified SWPPT. Where setting up an SWPPP is appropriate, it is important to identify key people on-site who are most familiar with the facility and its operations, and to provide adequate structure and direction to the facility's entire stormwater management program. Limitations involved in developing an internal reporting system are the potential lack of corporate commitment in designating appropriate funds, inadequate staff hours available for proper implementation, and a potential lack of motivation from SWPPT members that could inhibit the transfer of key stormwater pollution information.

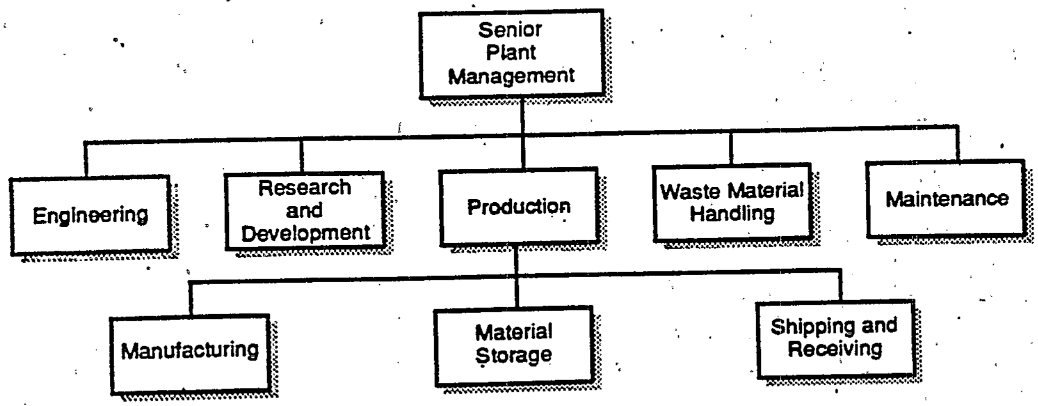
PERFORMANCE

The performance and effectiveness of an internal reporting system is highly variable and dependent upon several factors. Key factors include:

- Commitment of senior management.
- Sufficient time and financial resources.
- Quality of implementation.
- Background and experience of the SWPPT members.

DESIGN CRITERIA

When establishing an internal reporting structure, it is important to select appropriate personnel to serve on the team. Both team and individual responsibilities should be designated with clear goals defined for proper stormwater management. Internal reporting should be tied to other baseline BMPs such as employee training, individual inspections, and record keeping to ensure proper implementation. Figure 1 below illustrates an example SWPPT organization chart.



SOURCE: Reference 2

FIGURE 1: EXAMPLE SWPPT ORGANIZATION CHART

MAINTENANCE

To ensure that an internal reporting system remains effective, the person or team responsible for maintaining the SWPPP must be aware of any changes in plant operations or key team members to determine if modifications must be made in the overall execution of the SWPPP.

COSTS

Costs associated with implementing an internal reporting system are those associated with additional staff hours and related overhead costs. Annual costs can be estimated using the example shown in Table 1 below. Figure 2 can be used as a worksheet to calculate the estimated costs for an internal record keeping program.

TABLE 1: EXAMPLE OF ANNUAL INTERNAL REPORTING COSTS

Title	Quantity		Avg. Hourly Rate ($)		Overhead* Multiplier		Estimated Yearly Hours on SW Training		Est. Annual Cost ($)
Stormwater Engineer	1	x	15	x	2.0	x	20	=	600
Plant Management	5	x	20	x	2.0	x	10	=	2,000
Plant Employees	100	x	10	x	2.0	x	5	=	10,000
			TOTAL ESTIMATED ANNUAL COST						$12,600

SOURCE: EPA

Note: Defined as a multiplier (typically ranging between 1 and 3) that takes into account those costs associated with payroll expenses, building expenses, etc.

Title	Quantity		Avg. Hourly Rate ($)		Overhead Multiplier		Estimated Yearly Hours on SW Training		Est. Annual Cost ($)	
______	______	x	______	x	______	x	______	=	______	(A)
______	______	x	______	x	______	x	______	=	______	(B)
______	______	x	______	x	______	x	______	=	______	(C)
______	______	x	______	x	______	x	______	=	______	(D)

TOTAL ESTIMATED ANNUAL COST ______
(Sum of A+B+C+D)

SOURCE: Reference 2.

FIGURE 2: SAMPLE ANNUAL INTERNAL REPORTING COST WORKSHEET

REFERENCES

1. U.S. EPA, NPDES BMP Guidance Document, June 1981.
2. U.S. EPA, Stormwater Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices, September, 1992.

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MTB

Office of Wastewater Enforcement & Compliance
MUNICIPAL TECHNOLOGY BRANCH

STORM WATER BMP: MATERIALS INVENTORY

DESCRIPTION

A materials inventory system involves the identification of all sources and quantities of materials that may be exposed to direct precipitation or storm water runoff at a particular site. Significant materials are substances related to industrial activities such as process chemicals, raw materials, fuels, pesticides, and fertilizers. When these substances are exposed to direct precipitation or storm water runoff, they may be carried to a receiving waterbody. Therefore, identification of these substances and other materials helps to determine sources of potential contamination and is the first step in pollution control.

CURRENT STATUS

Most facilities already have in place a materials inventory system. However, the inventory of significant materials is not generally performed from a storm water contamination viewpoint. Modification of the existing materials inventory program to include storm water considerations should be minimal. The inventory should be incorporated into the Storm Water Pollution Prevention Plan (SWPPP).

APPLICATIONS

A materials inventory system is applicable to most industrial facilities. Inventory of exposed materials should be part of a baseline administrative program and is directly related to both record keeping and visual inspection Best Management Practices (BMP).

LIMITATIONS

Limitation of materials inventory system BMP include:

- It is an on-going process that continually needs updating.
- Qualified personnel are required to perform the materials inventory from a storm water perspective.
- Materials inventory records should be readily accessible.

PERFORMANCE

It is not possible to quantify water quality benefits to receiving waters of a materials inventory program since the program is intended to prevent pollution before it occurs. However, it is anticipated that an effective materials inventory program will result in improved storm water discharge quality.

DESIGN CRITERIA

Keeping an up-to-date inventory of all materials (hazardous and non-hazardous) on the site will help to limit material costs caused by overstocking, track how materials are stored and handled on site, and identify which materials and activities pose the greatest risk to the environment. The following basic steps should be used in completing a materials inventory:

- Identify all chemical substances present in the work place. Walk through the facility and review the purchase orders for the previous year. List all chemical substances used in the work place and then obtain the material safety data sheets (MSDS) for each.

- Label all containers to show the name and type of substance, stock number, expiration date, health hazards, suggestions for handling, and first aid information. This information can usually be found on the MSDS. Unlabeled chemicals and chemicals with deteriorated labels are often disposed of improperly or unnecessarily.

- Clearly mark on the inventory hazardous materials that require specific handling, storage, use, and disposal considerations.

Improved material tracking and inventory practices, such as instituting a shelf life program, can reduce the wastes resulting from overstocking and the disposal of outdated materials. Careful tracking of all materials ordered may also result in more efficient materials use. Figure 1 below illustrates a simple material inventory tracking system.

Based on your materials inventory, describe the significant materials that were exposed to storm water during the past three years and/or are currently exposed. Other BMPs should then be evaluated and implemented or constructed to eliminate exposure of theses materials to storm water or that provide appropriate treatment before discharge to receiving waters. Figure 2 below illustrates a sample worksheet for evaluating exposed materials.

MATERIAL INVENTORY

Worksheet
Completed by: ____________________
Title: ____________________
Date: ____________________

Instructions: List all materials used, stored, or produced onsite. Assess and evaluate these materials for their potential to contribute pollutants to storm water runoff.

Material	Purpose/Location	Quantity (units)			Quantity Exposed in Last 3 Years	Likelihood of contact with storm water. If yes, describe reason.	Past Significant Spill or Leak	
		Used	Produced	Stored			Yes	No

SOURCE: Reference 2.

FIGURE 1: SAMPLE MATERIAL INVENTORY

DESCRIPTION OF EXPOSED SIGNIFICANT MATERIAL

Worksheet
Completed by: ______________________
Title: ______________________
Date: ______________________

Instructions: Based on your material inventory, describe the significant materials that were exposed to storm water during the past three years and/or are currently exposed.

Description of Exposed Significant Material	Period of Exposure	Quantity Exposed (units)	Location (as indicated on the site map)	Method of Storage or Disposal (e.g., pile, drum, tank)	Description of Material Management Practice (e.g., pile covered, drum sealed)

SOURCE: Reference 2

FIGURE 2: EXPOSED MATERIAL WORKSHEET

MAINTENANCE

The key to a proper materials inventory system is continual updating of records. Maintaining an up-to-date materials inventory is an efficient way to identify what materials are handled on-site that may contribute to storm water contamination problems.

COSTS

The major cost of implementing a materials inventory system is the time required to implement a program that places emphasis on storm water quality. Typically, this is a small incremental increase if a materials inventory program already exists at the facility. Keeping an up-to-date inventory of all materials present on your site will help to keep material costs down by identifying waste and overstocking.

REFERENCE

1. U.S. EPA, NPDES Best Management Practices Guidance Document, December 1979.

2. U.S. EPA, Storm water Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices, September, 1992.

This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC, 20460.

STORM WATER BMP: NON-STORM WATER DISCHARGES

DESCRIPTION

Identifying and eliminating non-storm water discharges is an important and very cost-effective Best Management Practice (BMP). Examples of non-storm water discharges include process water, leaks from portable water tanks or pipes, excess landscape watering, vehicle wash water, and sanitary wastes. Non-storm water discharges are typically the result of unauthorized connections of sanitary or process wastewater drains that discharge to the storm sewer rather than to the sanitary sewer. Connections of non-storm water discharges to a storm water collection system are common, yet often go undetected. Another form of non-storm water discharge is wash water discharge to a storm drain. Typically these discharges are significant sources of pollutants, and unless regulated by an NPDES permit, are illegal.

CURRENT STATUS

Identifying and eliminating non-storm water discharges as a BMP have rarely been used at industrial facilities. Part of the problem is educational. Many facility operators are unaware of what constitutes a non-storm water discharge, and the potential impact. The new NPDES permit requirements for the presence of non-storm water discharges will greatly improve the implementation of this BMP.

APPLICATIONS

Identification of potential non-storm water discharges is applicable to almost every industrial facility that has not been tested or evaluated for the presence of such non-storm water discharges. Generally, a non-storm discharge evaluation includes:

- Identification of potential non-storm water discharges locations.
- Results of a physical site evaluation for the presence of non-storm water discharges.
- The evaluation criteria or test method used.
- The date of testing and/or evaluation.
- The on-site drainage points that were directly observed during the test and/or evaluation.

LIMITATIONS

Possible problems in identifying non-storm water discharges include:

- The possibility that a non-storm water discharge may not occur on the date of the test or evaluation.
- The method used to test or evaluate the discharge may not be applicable to the situation.
- Identifying an illicit connection may prove difficult due to the lack of available data on the location of storm drains and sanitary sewers, especially in older industrial facilities.

PERFORMANCE

The question of whether or not the elimination of non-storm water discharges is an effective BMP is answered by evaluating the environmental impact of these discharges. If a significant loading of pollutants is common from these discharges, then their elimination will be an effective BMP.

Several studies exist on the contents of non-storm water discharges. Pitt and Shawley (1982) reported that non-storm water discharges were found to contribute substantial quantities of many pollutants, even though the concentrations were not high. The long duration of the base flows offset the lower concentration leading to a substantial loading of pollutants. Gartner, Lee and Associates, Ltd. (1983) conducted an extensive survey of non-storm water discharges in the Humber River watershed (Toronto). Out of 625 outfalls, about 10 percent were considered significant pollutant sources. Further investigations identified many industrial and sanitary non-storm water discharges into the storm drainage system. For example, problems found in industrial areas included liquid dripping from animal hides stored in tannery yards and washdowns of storage yards at meat packing facilities. Therefore, it is anticipated that elimination of non-storm water discharges will be a highly effective BMP.

DESIGN CRITERIA

Key program criteria includes the identification and location of non-storm water entries into storm drainage systems. It is important to note that for any effective investigation of pollution within a storm water system, all pollutant sources must be included. For many pollutants, storm water may contribute the smaller portion of the total pollutant mass discharged from a storm drainage system. Significant pollutant sources may include dry-weather entries occurring during both warm and cold months and snowmelt runoff, in addition to conventional storm water associated with rainfall. consequently, much less pollution reduction benefit will occur if only storm water is considered in a control plan for controlling storm drainage discharges. The investigations may also identify illicit point source outfalls that do not carry storm water. Obviously, these outfalls also need to be controlled and permitted. Figure 1 below can be used as a sample worksheet to report non-storm water discharges.

NON-STORM WATER DISCHARGE

Worksheet
Completed by: ____________
Title: ____________
Date: ____________

Date of Test or Evaluation	Outfall Directly Observed During the Test (identify as indicated on the site map)	Method Used to Test or Evaluate Discharge	Describe Results from Test for the Presence of Non-Storm Water Discharge	Identify Potential Significant Sources	Name of Person Who Conducted the Test or Evaluation

SOURCE. Reference 4.

FIGURE 1: SAMPLE WORKSHEET FOR RECORDING NON-STORM WATER DISCHARGES

There are four primary methods for investigating non-storm water discharges. These methods include:

- Sanitary and Storm Sewer Map Review. A review of a plant schematic is a simple way to determine if there are any unauthorized connections to the storm water collection system. A sanitary or storm sewer map, or plant schematic is a map of pipes and drainage systems used to carry process wastewater, non-contact cooling water, and sanitary wastes. These maps (especially as-built plans or record drawings of the facility) should be reviewed to verify that there are no unauthorized connections. A common problem is that sites often do not have accurate or current schematics or plans.

- Visual Inspection. The most simple method for detecting non-storm water connections in the storm water collection system is to observe all discharge points during periods of dry weather. Key parameters to look for are the presence of stains, smudges, odors, and other abnormal conditions.

- Sampling and Chemical Analysis. Sewer mapping and visual inspection are also helpful in identifying locations for sampling. Chemical tests are needed to supplement the visual or physical inspections. Chemical tests can help quantify the approximate components of the mixture at the outfall or discharge point. Samples should be collected, stored, and analyzed in accordance with standard quality control and quality assurance (QA\QC) procedures. Statistical analysis of the chemical test results can be used to estimate the relative magnitude of the various flow sources. In most cases, non-storm water discharges are made up of may separate sources of flow (such as leaking domestic water systems, sanitary discharges, ground water infiltration, automobile washwater, etc.). Key parameters that can be helpful in identifying the source of the no -storm water flows include, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), specific conductivity, temperature, fluoride, hardness, ammonia ammonium, potassium, surfactant fluorescence, pH, total available chlorine, and toxicity screening. It may be possible to identify the source of the non-storm water discharge by examining the flow for specific chemicals.

  Just as high levels of pathogenic bacteria are usually associated with a discharge from a sanitary, waste water sources, the presence of certain chemicals are generally associated with specific industries. Table 1 below includes a listing of various chemicals that may be associated with a variety of different activities.

- Dye Testing. Another method for detecting improper connections to the storm water collection system is dye testing. A dye test can be performed by simply releasing a dye (either pellet or powder) into either the sanitary or process wastewater system. Discharge points from the storm water collection system are them examined for color change.

MAINTENANCE

A maintenance program consists of annual inspections for non-storm water discharges, even if previous tests have been negative. New processes, building additions, and other plant changes, if they are not carefully reviewed during design, may result in future unauthorized connections to the storm water conveyance system.

TABLE 1: CHEMICALS COMMONELY FOUND INDUSTRIAL DISCHARGES

Chemical:	Industry:
Acetic acid	Acetate rayon, pickle and beetroot manufacture
Alkalies	Cotton and straw kiering, cotton manufacture, mercerizing, wool scouring, laundries
Ammonia	Gas and coke manufacture, chemical manufacture
Arsenic	Sheep-dipping, felt mongering
Chlorine	Laundries, paper mills, textile bleaching
Chromium	Plating, chrome tanning, aluminum anodizing
Cadmium	Plating
Citric acid	Soft drinks and citrus fruit processing
Copper	Plating, pickling, rayon manufacture
Cyanides	Plating, metal cleaning, case-hardening, gas manufacture
Fats, oils	Wool scouring, laundries, textiles, oil refineries
Fluorides	Gas and coke manufacture, chemical manufacture, fertilizer plants, transistor manufacture, metal refining, ceramic plants, glass etching
Formalin	Manufacture of synthetic resins and penicillin
Hydrocarbons	Petrochemical and rubber factories
Hydrogen peroxide	Textile bleaching, rocket motor testing
Lead	Battery manufacture, lead mining, paint manufacture, gasoline manufacture
Mercaptans	Oil refining, pulp mills
Mineral acids	Chemical manufacture, mines, Fe and Cu pickling, brewing, textiles, photoengraving, battery manufacture
Nickel	Plating
Nitro compounds	Explosives, and chemical works
Organic acids	Distilleries and fermentation plants
Phenols	Gas and coke manufacture, synthetic resin manufacture, textiles, tanneries, tar, chemical, and dye manufacture, sheep-dipping
Silver	Plating, photography
Starch	Food, textile, wallpaper manufacture
Sugars	Dairies, foods, sugar refining, preserves, wood process
Sulfides	Textiles, tanneries, gas manufacture, rayon manufacture
Sulfites	Wood process, viscose manufacture, bleaching
Tannic acid	Tanning, sawmills
Tartaric acid	Dyeing, wine, leather, and chemical manufacture
Zinc	Galvanizing, plating, viscose manufacture, rubber process

SOURCE: Reference 7.

COSTS

The above methods are mostly time-intensive and their cost are dependent on the amount of effort and level of expertise employed. Visual inspections are the least expensive of the three. Dye testing may be more cost effective for buildings that do not have current schematics of their sanitary and storm sewer systems. The cost of disconnecting illicit discharges from the storm water system will vary depending on the type and location of the connection and the type of corrective action needed.

The Full use of all of the applicable procedures is most likely necessary to successfully identify pollutant sources. Attempting to reduce costs, for example, by only examining a certain class of outfalls, or using inappropriate testing procedures, will significantly reduce the utility of the testing program and result in inaccurate conditions.

ENVIRONMENTAL IMPACTS

Eliminating non-storm water discharges can have significant impacts on improving water quality in the receiving waters.

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6. California Environmental Protection Agency, Staff Proposal for Modification to Water Quality Order No. 91-13 DWQ Waste Discharge Requirements for Discharges of Storm water Associated with Industrial Activities, Draft, August 1992.

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STORM WATER BMP: POROUS PAVEMENT

DESCRIPTION

Porous pavement is a specially designed and constructed pavement which allows stormwater to pass through it. The purpose of porous pavement is to reduce the speed and amount of runoff from a site, and to filter potential pollutants from the stormwater. There are two principal types of porous pavement: porous asphalt pavement, and pervious concrete pavement. Porous asphalt pavement consists of an open graded coarse aggregate bound together by asphalt with sufficient interconnected voids to provide a high rate of water percolation. Pervious concrete consists of specially formulated mixtures of Portland cement, uniform open graded coarse aggregate, and water. When properly handled and installed, pervious concrete has a high percentage of void space which allows rapid percolation of liquids through the pavement.

The porous pavement surface is typically placed over a highly permeable layer of open graded gravel and crushed stone. The void spaces in the aggregate layers provide a storage reservoir for runoff. A filter fabric is placed beneath the gravel and stone layers to prevent the movement of fine soil particles into these layers. Figure 1 below illustrates a common porous asphalt pavement installation.

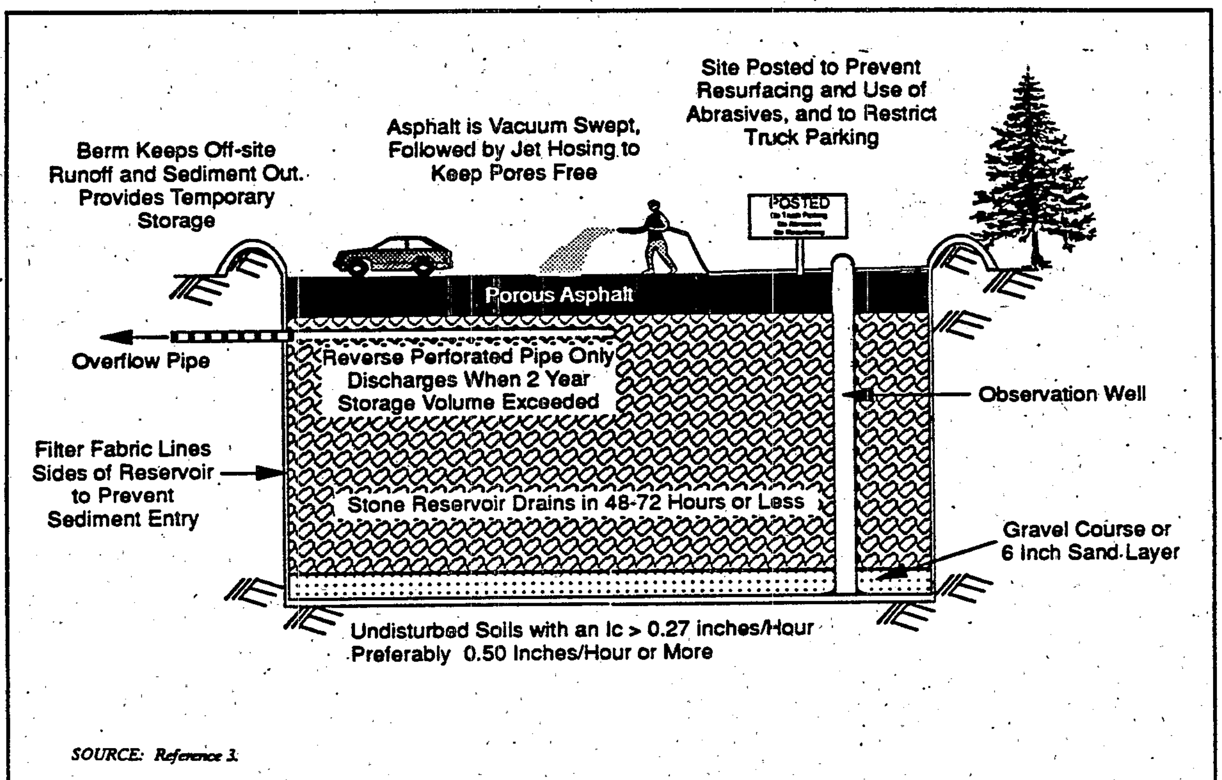


FIGURE 1: TYPICAL POROUS PAVEMENT INSTALLATION

Porous pavement offers a number of advantages including:

- Provides water quality improvement by removing pollutants.

- Reduces the need for curbing and storm sewer installation.

- Improves road safety by increasing skid resistance. (Tests have shown that there is up to 15 percent less hydro-planing and skidding on porous pavement surfaces.)

- Provides recharge to local aquifers.

COMMON MODIFICATIONS

A common modification for porous pavement design systems consists of varying the amount of storage to be provided in the stone reservoir located directly beneath the pavement, and adding perforated pipes near the top of the reservoir to discharge stormwater runoff after the reservoir has been filled to design capacity. Stone reservoirs may be designed to accept the first flush of stormwater runoff or provide enough storage to accommodate runoff from a chosen design storm for infiltration through the underlying subsoil. Pretreatment of off-site runoff is highly recommended. Another variation of pervious concrete is the use of a concrete block or brick system with individual blocks separated by a pervious material.

CURRENT STATUS

Currently there is little information on porous pavement. However, in general information about infiltration trenches and basins also applies to porous pavement. The following concerns are currently being evaluated by the EPA.

- Can pavement porosity be maintained over the long term, particularly with resurfacing needs and snow removal?

- What is the pollutant removal capability of porous pavement during subfreezing weather and snow removal conditions?

- What are the optimal relationships between porous pavement, groundwater, sandy soils, and high water table conditions?

- What are the costs of maintenance and rehabilitation options for restoration of porosity?

APPLICATIONS

Porous pavement is applicable as a substitute for conventional pavement on parking areas and low traffic volume roads provided that the grades, subsoils, drainage characteristics, and groundwater table conditions are suitable. Slopes should be very gentle to flat. Soils should have field-verified permeability rates of greater than 0.5 inches per hour, and there should be a 4-foot minimum clearance from the bottom of the system to bedrock or the water table. Additional areas for use of porous pavement include fringe overflow parking areas and taxiway and runway shoulders at airports.

LIMITATIONS

The use of porous pavement may be restricted in regions with extremely cold climates, arid regions or regions with high wind erosion rates (increased windblown sediment loads) and areas where sole source potable aquifers could be contaminated. The .e of porous pavement is highly constrained, requiring deep permeable soils, restricted traffic, and adjacent land uses. Some specific disadvantages of porous pavement include:

- The lack of experience with this technology with most pavement engineers and contractors.
- Porous pavement has a tendency to become clogged if improperly installed or maintained.
- The high failure rate of porous pavement sharply limits the ability to meet watershed stormwater quality and quantity goals.
- Slight to moderate risk of groundwater contamination depending on soil conditions and aquifer susceptibility.
- Possible transport of hydrocarbons from vehicles and leaching of toxic chemicals from asphalt and/or binder surface.
- Some building codes may not allow for the installation of porous pavement.
- The possibility exists that anaerobic conditions may develop in underlying soils if the soils, are unable to dry out between storm events.

PERFORMANCE

Traditionally, porous pavement sites have had a high failure rate (75 percent). Failure has been attributed to poor design, inadequate construction techniques, low permeability soils, heavy vehicular traffic, and resurfacing with nonporous pavement materials.

Porous pavement pollutant removal mechanisms include absorption, straining, and microbiological decomposition in the soil underlying the aggregate chamber and trapping of particulate matter within the chamber. An estimate of porous pavement pollutant removal efficiency is provided by two long-term monitoring studies. These studies indicate long-term removal efficiencies of between 82 and 95 percent for sediment, 65 percent for total phosphorus, and 80-85 percent of total nitrogen. They also indicated high removal rates for zinc, lead, and chemical oxygen demand. Some key factors to increase pollutant removal and prevent failure include:

- Routine vacuum sweeping and high pressure washing.
- Maximum recommended drainage time of 24 hours.
- Highly permeable soils.
- Pretreatment of off-site runoff.
- Inspection and enforcement of specifications during construction.
- Organic matter in subsoils.
- Clean-washed aggregate.
- Use only in low-intensity parking areas.
- Restrictions on use by heavy vehicles.
- Limiting use of de-icing chemicals and sand.

DESIGN CRITERIA

Porous pavement, along with other infiltration BMPs (infiltration basins, trenches, etc.) have demonstrated relatively short life spans in the past. Failures have general been attributed to poor design, poor construction techniques, subsoils with low permeability, and lack of adequate preventive maintenance. Key design factors that can significantly increase the performance and reduce the risk of failure of porous pavements and other infiltration BMPs is shown in Table 1 below.

TABLE 1: DESIGN CRITERIA FOR POROUS PAVEMENT

Design Criteria	Guidelines
Site Evaluation	• Take soil borings to depth of at least 4 feet below bottom of stone reservoir to check for soil permeability, porosity, depth to seasonally high water table, and depth to bedrock.
	• Not recommended on slopes greater than 5 percent and best with slopes as flat as possible.
	• Minimum infiltration rate 3 feet below bottom of stone reservoir: 0.5 inches per hour.
	• Minimum depth to bedrock and seasonally high water table: 4 feet.
	• Minimum setback from water supply wells: 100 feet.
	• Minimum setback from building foundations: 10 feet downgradient, 100 feet upgradient.
	• Not recommended in areas where wind erosion supplies significant amounts of windblown sediment.
	• Drainage area should be less than 15 acres.
Traffic Conditions	• Use for low volume automobile parking areas and lightly used access roads.
	• Avoid moderate to high traffic areas and significant truck traffic.

SOURCE: Reference 2.

TABLE 1: DESIGN CRITERIA FOR POROUS PAVEMENTS.

(CONTINUED)

Design Criteria	Guidelines
	• While the standard porous pavement design is believed to withstand freeze/thaw conditions normally encountered in most regions of the country, the porous pavement system is sensitive to clogging during snow removal operations. Therefore, the area should be posted with signs to restrict the use of sand, salt, and other deicing chemicals typically associated with snow cleaning activities.
Design Storm Storage Volume	• Literature values suggest this parameter is highly variable and dependent upon regulatory requirements. One typically recommended storage volume is the stormwater runoff volume produced in the tributary watershed by the produced in the tributary watershed by the 6-month, 24-hour duration storm event.
Drainage Time for Design Storm	• Minimum: 12 hours. • Maximum: 72 hours. • Recommended: 24 hours.
Construction	• Excavate and grade with light equipment with tracks or oversized tires to prevent soil compaction. • As needed, divert stormwater runoff away from planned pavement area to keep runoff and sediment away from site before and during construction. • A typical porous pavement cross-section consists of the following layers: 1) porous asphalt course, 2-4 inches thick; 2) filter aggregate course; 3) reservoir coarse of 1.5-3-inch diameter stone; and 4) filter fabric.
Porous Pavement Placement	• Pavement temperature: 240-260° F. • Minimum air temperature: 50° F. • Compact with one or two passes of a 10-ton roller. • Prevent any vehicular traffic on pavement for at least two days. Pretreatment•Pretreatment is recommended to treat runoff from all off-site areas. An example would be a 25-foot wide vegetative filter strip placed around the perimeter of the porous pavement where drainage flows onto the pavement surface.

SOURCE: Reference 2.

MAINTENANCE

Routine maintenance of porous pavements is extremely important. Maintenance should include vacuum sweeping at least four times per year, followed by high-pressure hosing to limit sediment clogging in the pores of the top layer. Potholes and cracks can be filled with typical patching mixes unless more than 10 percent of the surface area needs repair. Spot-clogging may be fixed by drilling half-inch holes through the porous pavement layer every few feet.

The pavement should be inspected several times during the first few months following installation and then annually thereafter. Inspections after large storms are necessary to check for pools of water. These pools may indicate clogging. The condition of adjacent pretreatment facilities should also be inspected.

COSTS

The costs of developing a porous pavement system 100 feet by 50 feet and with a 4 foot deep storage area can be estimated using the example in table 2 below.

Estimated costs for an average annual maintenance program of a porous pavement parking lot are approximately $200 per acre per year. This cost assumes four inspections, vacuum sweeping and jet hosing treatments per year.

TABLE 2: ESTIMATED COSTS FOR A POROUS PAVEMENT SYSTEM

1.	Excavation Costs:	740 cy x $5.00/cy	$ 3,700
2.	Filter Aggregate/Stone Fill	740 cy x $20.00/cy	14,800
3.	Filter Fabric	760 sy x $3.00/sy	2,280
4.	Porous Pavement	556 sy x $13.00/sy	7,228
5.	Overflow Pipes	200 ft x $12.00/ft	2,400
6.	Observation Well	1 at $200 ea	200
7.	Grass Buffer	833 sy x $1.50/sy	1,250
8.	Erosion Control	$1,000/lump sum	1,000
		SUBTOTAL	$32,858
9.	Contingencies (Engineering, Administration, etc.) = 25%		8,215
		TOTAL*	$41,073

SOURCE: Reference 4.

* Costs for traditional pavement, including any storm sewers, curb and gutter should be subtracted from this amount to reflect the difference in total cost for implementing a porous pavement system. Unit costs will vary according to local market conditions.

ENVIRONMENTAL IMPACTS

One potential negative impact of porous pavement is the risk of groundwater contamination. Pollutants (such as nitrates and chlorides) not easily trapped, absorbed, or reduced may continue to move through the soil profile and into groundwater. This is not a desirable condition, as it could lead to contamination of drinking water supplies. Therefore, until more scientific data is available, it is advisable not to site porous pavement near groundwater drinking supplies.

REFERENCES

1. A Current Assessment of Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in a Coastal Zone, December 1991.

2. Field, Richard et al., An Overview of Porous Pavement Research, Water Resources Bulletin, Volume 18, No. 2, pp. 265-267, 1982.

3. Metropolitan Washington Council of Governments, Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs, 1987.

4. Southeastern Wisconsin Regional Planning Commission, Costs of Urban Nonpoint Source Water Pollution Control Measures, Technical Report No. 31, June 1991.

5. U.S. EPA, Best Management Practices Implementation Manual, April 1981.

6. U.S. EPA, Stormwater Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices, September 1992.

7. Washington State Department of Ecology, Stormwater Management Manual for the Puget Sound Basin, February 1992.

This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC, 20460.

STORM WATER BMP: PREVENTIVE MAINTENANCE

DESCRIPTION

Preventive maintenance involves the regular inspection and testing of plant equipment and operational systems. These inspections should uncover conditions such as cracks or slow leaks which could cause breakdowns or failures that result in discharges of chemicals to surface waters either by direct overland flow or through storm drainage systems. The purpose of the preventive maintenance program should be to prevent breakdowns and failures by adjustment, repair, or replacement of equipment before a major breakdown or failure can occur.

Preventive maintenance has been practiced predominantly in those industries where excessive down time is extremely costly. As a storm water best management practice BMP, preventive maintenance should be used selectively to eliminate or minimize the spill of contaminants to receiving waters. For many facilities this would simply be an extension of the current plant preventive maintenance program to include items to prevent storm water runoff contamination.

For sites that have storm drainage facilities, proper maintenance is necessary to ensure that they serve their intended function. Without adequate maintenance, sediment and other debris can quickly clog facilities and render them useless. Typically, a preventive maintenance program should include inspections of catch basins, storm water detention areas, and water quality treatment systems.

CURRENT STATUS

Most plants already have preventive maintenance programs that provide some degree of environmental protection. This program could be expanded to include stormwater considerations, especially the upkeep and maintenance of storage tanks, valves, pumps, pipes, and storm water management devices.

APPLICATIONS

Preventive maintenance procedures and activities are applicable to almost every industrial facility. Preventive maintenance should be part of a general good housekeeping program designed to maintain a clean and orderly work environment. Often the most effective first step towards preventing storm water pollution from industrial sites simply involves good common sense to improve the facility preventive maintenance and general good housekeeping methods.

LIMITATIONS

Primary limitations of implementing a preventive maintenance program include:

- Additional costs.
- Availability of trained preventive maintenance staff technicians.
- Management direction and staff motivation in expanding the preventive maintenance program to include storm water considerations.

PERFORMANCE

Quantitative data is not available on the effectiveness of preventive maintenance as a best management practice. However, it is clear that an effective preventive maintenance program can result in improved storm water discharge quality.

DESIGN CRITERIA

Elements of a good preventive maintenance program should include:

- Identification of equipment or systems which may malfunction and cause spills, leaks, or other situations that could lead to contamination of storm water runoff. Typical equipment to inspect include pipes, pumps, storage tanks and bins, pressure vessels, pressure release valves, process and material handling equipment, and storm water management devices.
- Once equipment and areas to be inspected have been identified at the facility, establish schedules and procedures for routine inspections.
- Periodic testing of plant equipment for structural soundness is a key element in a preventive maintenance program.
- Promptly repair or replace defective equipment found during inspection and testing.
- Keep spare parts for equipment that need frequent repair.
- It is important to include a record keeping system for scheduling tests and documenting inspections in the preventive maintenance program.
- Record test results and follow up with corrective action taken. Make sure records are complete and detailed. These records should be kept with other visual inspection records.

MAINTENANCE RECORDS

The key to properly tracking a preventive maintenance program is through the continual updating of maintenance records. Records should be updated immediately after preventive maintenance, or when any repair has been performed on any item in the plant. An annual review of these records should be conducted to evaluate the overall effectiveness of the preventive maintenance program. Refinements to the preventive maintenance procedures and tasking should be implemented as necessary.

COSTS

The major cost of implementing a preventive maintenance program that places emphasis on storm water quality is the staff time required to implement the program. Typically, this is a small incremental increase if a preventive for training and maintenance program already exists at the facility.

REFERENCES

1. U.S. EPA, NPDES best management practice Guidance Document, June 1981.

2. U.S. EPA, Storm water Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices, September, 1992.

3. Washington State Department of Ecology, Storm water Management Manual for Puget Sound, February 1992.

This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC 20460.

STORM WATER BMP: RECORD KEEPING

DESCRIPTION

A record keeping system should be implemented for documenting spills, leaks, and other discharges such as hazardous substances. Keeping records and reporting events that occur on-site are effective ways of tracking the progress of pollution prevention efforts and waste minimization. Analyzing records of past spills can provide useful information for developing improved Best Management Practices (BMPs) to prevent future spills. Record keeping represents a good operating practice because it can increase the efficiency of a facility by reducing down time and increase the effectiveness of other prevention and treatment BMPs. Typical record keeping items include reported incidents and follow-up on results of inspections, and reported spills, leaks, or other discharges.

IMPLEMENTATION

Record keeping as a BMP should be an integral part of a BMP implementation program and should be incorporated into Stormwater Pollution Prevention Plans (SWPPP).If a separate record keeping system for tracking BMPs, monitoring results, etc., is not currently in place at a facility, existing record keeping structures could be easily adapted to incorporate this data. An ideal tool for implementation is the record keeping procedures laid out in an SWPPP. In many cases the record keeping system can be maintained on a personal or desk top computer using standard spreadsheet or data base management software.

LIMITATIONS

Limitations associated with a record keeping system are:

- It is an on-going process that continually needs updating.
- Qualified personnel required to complete the record keeping forms.
- Accessible of records.
- Security of confidential information.

PERFORMANCE

Record keeping performance as a BMP is highly variable. It depends on the time and commitment dedicated to implementing an effective system. The benefit of an effective record keeping system being incorporated into an overall SWPPP is improved stormwater discharge leaving facility grounds. The effectiveness of the record keeping system is often dependent on the following:

- The commitment of senior management to implementing and maintaining an effective record keeping system.
- The quality of the record keeping program.
- The background and experience of the assigned record keeping team.

DESIGN CRITERIA

Record keeping and reporting procedures for spills, leaks, inspections, maintenance, and monitoring activities should include the following. a sample worksheet for keeping records of spills and leaks is shown in Figures 1 below.

- The date, location, and time of material inventories, site inspections, sampling observations, etc.
- The individual(s) who performed site inspections, sampling observations, etc.
- The date(s) analyses were performed and the time(s) analyses were initiated, the individual or individual(s) who performed the analyses, analytical techniques or methods used, and results of such analysis.
- Quality assurance/quality control results.
- The date, time, exact location,and complete characterization of significant spills or leaks.
- Visual observation and sample collection exception records.
- All calibration and maintenance records of instruments used in stormwater monitoring.
- All original strip chart recordings for continuous monitoring equipment.

LIST OF SIGNIFICANT SPILLS AND LEAKS

Worksheet
Completed by: ____________
Title: ____________
Date: ____________

Directions: Record below all significant spills and significant leaks of toxic or hazardous pollutants that have occurred at the facility in the three years prior to the effective date of the permit.

Definitions: Significant spills include, but are not limited to, releases of <u>oil</u> or <u>hazardous substances in excess of reportable quantities</u>.

1st Year Prior				Description				Response Procedure		
Date (month/day/year)	Spill	Leak	Location (as indicated on site map)	Type of Material	Quantity	Source, If Known	Reason	Amount of Material Removed	Material No Longer Exposed to Storm Water (True/False)	Preventive Measures Taken

2nd Year Prior				Description				Response Procedure		
Date (month/day/year)	Spill	Leak	Location (as indicated on site map)	Type of Material	Quantity	Source, If Known	Reason	Amount of Material Removed	Material No Longer Exposed to Storm Water (True/False)	Preventive Measures Taken

3rd Year Prior				Description				Response Procedure		
Date (month/day/year)	Spill	Leak	Location (as indicated on site map)	Type of Material	Quantity	Source, If Known	Reason	Amount of Material Removed	Material No Longer Exposed to Storm Water (True/False)	Preventive Measures Taken

SOURCE: Reference 3.

FIGURE 1: SAMPLE WORKSHEET FOR TRACKING SPILLS AND LEAKS

MAINTENANCE

The key to a proper maintenance program for record keeping is continual updating. Records should be updated with the correct name and address of the facility, name and location of receiving waters, number and location of discharge points, principal product and significant changes in raw material storage outside, and reports of monitoring results and spills at the site. It is recommended that all reports be maintained for a period of at least five years from the date of sample observation, measurement, or spill report. Some simple techniques used to accurately document and report results include:

- Field notebooks
- Timed and dated photographs
- Videotapes
- Drawings and maps
- Computer spreadsheet and database programs

COSTS

Costs associated with implementing a record keeping system are those associated with additional staff hours to initially develop the system and to keep records up to date, along with related overhead costs. Annual costs can be estimated using the example shown in Table 1 below. Figure 4 can be used as a worksheet to calculate the estimated annual cost for a record keeping system.

TABLE 1: EXAMPLE OF ANNUAL RECORD KEEPING COSTS

Title	Quantity		Avg. Hourly Rate ($)		Overhead* Multiplier		Estimated Yearly Hours on SW Training		Est. Annual Cost ($)
Stormwater Engineer	1	x	15	x	2.0	x	20	=	600
Plant Management	5	x	20	x	2.0	x	10	=	2,000
Plant Employees	100	x	10	x	2.0	x	5	=	10,000
			TOTAL ESTIMATED ANNUAL COST						$12,600

Note: Defined as a multiplier (typically ranging between 1 and 3) that takes into account those costs associated with payroll expenses, building expenses, etc.

SOURCE: EPA

Title	Quantity		Avg. Hourly Rate ($)		Overhead Multiplier		Estimated Yearly Hours on SW Training		Est. Annual Cost ($)	
________	____	x	____	x	____	x	____	=	____	(A)
________	____	x	____	x	____	x	____	=	____	(B)
________	____	x	____	x	____	x	____	=	____	(C)
________	____	x	____	x	____	x	____	=	____	(D)
					TOTAL ESTIMATED ANNUAL COST (Sum of A+B+C+D)				____	

SOURCE: Reference 3.

FIGURE 2: SAMPLE ANNUAL RECORD KEEPING COST WORKSHEET

REFERENCES

1. California Environmental Protection Agency, Staff Proposal for Modification to Water Quality Order No. 91-13 DWQ Waste Discharge Requirements for Dischargers of Stormwater Associated with Industrial Activities, Draft Wording, Monitoring Program and Reporting Requirements, August 17, 1992.

2. U.S. EPA, NPDES BMP Guidance Document, June, 1981.

3. U.S. EPA, Stormwater Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices, September, 1992.

This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC 20460.

STORM WATER BMP: SPILL PREVENTION PLANING

DESCRIPTION

A Spill Prevention Plan identifies areas where spills can occur on site, specifies materials handling procedures, storage requirements, and identifies spill clean-up procedures. The purpose of this plan is to establish standard operating procedures, and the necessary employee training to minimize the likelihood of accidental releases of pollutants that can contaminate stormwater runoff. Spill Prevention is prudent from both an economic as well as environmental standpoint because spills increase operating costs and lower productive[1]

Storm water contamination assessment, flow division, record keeping, internal reporting, employee training, and preventive maintenance are associated BMPs that should be incorporate into a comprehensive Spill Prevention Plan.

CURRENT STATUS

Typically, most businesses and public agencies that generate hazardous waste and/or produce, transport, or store petroleum products are required by state and federal law to prepare spill control and cleanup plans. Therefore, a Spill Prevention and Response Plan may have already been developed in response to other environmental regulatory requirements. Existing plans should be re-evaluated and revised if necessary to address stormwater management issues.

APPLICATIONS

A Spill Prevention Plan is applicable to facilities that transport, transfer, and store hazardous materials, petroleum products, and fertilizers that can contaminate stormwater runoff. An important factor of an effective spill prevention plan is quick notification of the appropriate emergency response teams. In some plants each area or process may have a separate team leader and team of experts. Figure 1 below illustrates a sample spill prevention team roster for quick identification of team leaders and their responsibilities.

LIMITATIONS

Spill Prevention Planing can be limited by the following:

- Lack of employee motivation to implement plan.
- Lack of commitment from senior management.
- Key individuals identified in the Spill Prevention Plan may not be properly trained in the areas of spill prevention, response, and cleanup.

PERFORMANCE

Past experience has shown that the single most important obstacle to an effective Spill Prevention Plan is its implementation. Qualitatively, implementation of a well prepared Spill Prevention Plan should significantly decrease contamination of stormwater runoff.

POLLUTION PREVENTION TEAM MEMBER ROSTER	Worksheet Completed by: ____________ Title: ____________ Date: ____________

Leader: ____________ **Title:** ____________

Office Phone: ____________

Responsibilities: ____________

Members:

(1) ____________ **Title:** ____________

Office Phone: ____________

Responsibilities: ____________

(2) ____________ **Title:** ____________

Office Phone: ____________

Responsibilities: ____________

(3) ____________ **Title:** ____________

Office Phone: ____________

Responsibilities: ____________

SOURCE: Reference 1.

FIGURE 1: SAMPLE SPILL PREVENTION TEAM ROSTER

DESIGN CRITERIA

General guidelines for the preparation of a Spill Prevention Plan include:

- The first part of the plan should contain a description of the facility including the owner's name and address, the nature of the facility activity, and the general types of chemicals used in the facility.
- The plan should contain a site plan showing the location of storage areas for chemicals, location of the storm drains, tributary drainage areas with drainage arrows, and the location and description of any devices to stop spills from leaving the site such as collection basins.
- The plan should describe notification procedures to be used in the event of a spill such as phone numbers of key personnel, and appropriate regulatory agencies such as local Pollution Control Agencies and the local Sewer Authority.
- The plan should provide specific instructions regarding cleanup procedures.

- The owner, through an internal reporting procedure, should have a designated person with overall responsibility for spill response. Through an *employee training program*, key personnel should be trained in the use of this plan. All employees should have basic knowledge of spill control procedures.

- A summary of the plan should be written and posted at appropriate points in the building (i.e., lunch rooms, cafeteria, and areas with a high spill potential), identifying the spill cleanup coordinators, location of cleanup kits, and phone numbers of regulatory agencies to be contacted in the event of a spill.

- Cleanup of spills should begin immediately. No emulsifier or dispersant should be used.

- In fueling areas, absorbent should be packaged in small bags for easy use and small drums should be available for storage of absorbent and/or used absorbent. Absorbent materials shall not be washed down the floor drain or into the storm sewer.

- Emergency spill containment and cleanup kits should be located at the facility site. The contents of the kit should be appropriate to the type and quantities of chemical or goods stored at the facility.

Some structural methods to consider when developing a Spill Prevention Plan include:

- Containment diking-- Containment dikes are temporary or permanent earth or concrete berms or retaining walls that are designed to hold spills. Diking can be used at any industrial facility, but is most common for controlling large spills or releases from liquid storage and transfer areas. Diking can provide one of the best protective measures against the contamination of stormwater because it surrounds the area of concern and holds the spill, keeping spill materials separated from the stormwater outside of the diked area.

- Curbing-- Like containment diking, curbing is a barrier that surrounds an area of concern. Because curbing is usually small-scale, it cannot contain large spills like diking can. However, curbing is common at many facilities and small areas where liquids are handled and transferred.

- Collection basins. Collection basins are permanent structures where large spills or contaminated stormwater are contained and stored before cleanup or treatment. Collection basins are designed to receive spills, leaks, etc., that may occur and prevent these materials from being released to the environment. Unlike containment dikes, collection basins can receive and contain materials from many locations across a facility.

Once a hazardous material spill occurs and is contained, the material has to be cleaned up and disposed of to protect plant personnel from potential health and fire hazards, and to prevent the release of the substance to surface waters. Methods of cleanup, recovery, treatment, or disposal include:

- Physical. Physical methods for cleanup of dry chemicals include the use of brooms, shovels, sweepers, or plows.

- Mechanical. Mechanical methods for cleanup include the use of vacuum cleaning systems and pumps.

- Chemical. Chemical cleanup of material can be accomplished with the use of sorbents, gels, and foams. Sorbents are compounds that immobilize materials by surface absorption or adsorption in the sorbent bulk. Gelling agents interact with the spilled chemical(s) by concentrating and congealing to form a rigid or viscous material more conducive to mechanical cleanup. Foams are mixtures of air and aqueous solutions of proteins and surfactant-based foaming agents. The primary purpose of foams is to reduce the vapor concentration above the spill surface thereby controlling the rate of evaporation.

MAINTENANCE

A facility Spill Prevention Plan should be reviewed at least annually and following any spills to evaluate the Spill Prevention Plan's level of success and how it can be improved. Other times for significant review of the plan should be when a new material is introduced to the plant as a result of a processing modification, or when a change has occurred in a materials handling procedure.

COSTS

If a facility already has a Spill Control and Cleanup Plan in-place, modifications, to address stormwater contamination concerns, will require minimal cost. If a facility will be developing a Spill Prevention Plan for the first time, initial cost will depend on the type of materials at the facility, facility size, and other related parameters. Costs for structural containment devices will also need to be identified for each facility.

ENVIRONMENTAL IMPACTS

Preventing or containing spills, especially toxic or hazardous materials, is important in reducing storm water contamination and in maintaining the water quality of the receiving water.

REFERENCES

1. U.S. EPA, Stormwater Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices, September 1992.

2. Washington State Department of Ecology, Stormwater Management Manual for Puget Sound, February 1992.

This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC, 20460.

- Create a map of the facility site to locate pollutant sources and determine stormwater management opportunities. This site map should include all surface waterbodies on or next to the site, and should also identify, if any that are in place. Tributary drainage areas with identification of flow direction should also bed identified during this mapping phase. Table 1 contains a list of features that should be indicated on the site map.
- Conduct a material inventory throughout the facility.
- Evaluate past spills and leaks.
- Identify non-stormwater discharges and non-approved connections to stormwater facilities.
- Collect and evaluate stormwater quality data.
- Summarize the findings of this assessment.

TABLE 1: CRITERIA FOR DEVELOPING A SITE MAP

DEVELOPING A SITE MAP	Worksheet Completed by: ____________ Title: ____________ Date: ____________

Instructions: Draw a map of your site including a footprint of all buildings, structures, paved areas, and parking lots. The information below describes additional elements

- All outfalls and storm water discharges
- Drainage areas of each storm water outfall
- Structural storm water pollution control measures, such as:
  - Flow diversion structures
  - Retention/detention ponds
  - Vegetative swales
  - Sediment traps
- Name of receiving waters (or if through a Municipal Separate Storm Sewer System)
- Locations of exposed significant materials
- Locations of past spills and leaks
- Locations of high-risk, waste-generating areas and activities common on industrial sites such as:
  - Fueling stations
  - Vehicle/equipment washing and maintenance areas
  - Area for unloading/loading materials
  - Above-ground tanks for liquid storage
  - Industrial waste management areas (landfills, waste piles, treatment plants, disposal areas)
  - Outside storage areas for raw materials, by-products, and finished products
  - Outside manufacturing areas
  - Other areas of concern (specify: ____________)

SOURCE: Reference 1.

STORM WATER BMP: CONTAMINATION ASSESSMENT

DESCRIPTION

A Stormwater Contamination Assessment (SWCA) provides a review of a facility and site to determine what materials or practices may be a source of contaminants to the stormwater. The purpose of the assessment is to help target the most important pollutant sources for corrective and/or preventive action.

A SWCA program is closely related to other BMP's, such as materials inventory, non-stormwater discharges, record keeping, and visual inspections. To be effective these, and other BMP's should be incorporated into a comprehensive pollution prevention program.

APPLICATIONS

A SWCA program is applicable to any industrial facility which contains areas, activities, or materials which may contribute pollutants to stormwater runoff from the total site. An assessment for stormwater purposes may also be applicable in situations where a formal site assessment for hazardous waste purposes is being performed.

LIMITATIONS

Limitations associated with a contamination assessment program include:

- Assessments need to be performed by qualified personnel.
- A corporate commitment must exist to reduce the contamination sources once discovered.
- Assessments need to be periodically updated.

PERFORMANCE

It is not possible, based on currently available data, to quantify the water quality benefits to receiving waters of a stormwater contamination assessment program. Results are entirely based on the severity of the contamination uncovered, and the corrective actions taken. Qualitatively, implementation of a program that identifies areas of high pollutant concentrations and eliminate or reduces their potential pollutant capabilities will result in positive water quality benefits.

DESIGN CRITERIA

A SWCA program should include the following key activities:

- Assess potential pollutant sources and associated high risk activities such as loading and unloading operations, outdoor storage activities, outdoor manufacturing or processing activities, significant dust or particulate-generating activities, and on-site waste disposal practices.

Once you have completed the above steps in your pollutant source assessment, you have enough information to determine which areas, activities, or materials are a risk towards contributing pollutants to stormwater runoff from your site. An important benefit is that by using this information, you can effectively select other cost-effective BMPs to prevent or control pollutants.

IMPLEMENTATION

In addition to identifying problems within the storm sewer system, it is even more important to prevent problems from developing at all, and to provide an environment in which future problems can be avoided. Thus, an effective stormwater assessment program should include implementation activities to insure success and follow-up activities to measure results. Keys to a successful implementation program should include:

- Public education, on organized systematic program of disconnecting commercial and industrial stormwater entries into the storm drainage system.
- Tackling the problem of widespread septic system failure.
- Disconnecting direct sanitary sewerage connections.
- Rehabilitating storm or sanitary sewers to abate contaminated water infiltration.
- Developing zoning and other ordinances.

In extreme cases, it may be that while it was thought that a community had a separate sanitary sewer system and a separate storm sewer system, in reality the storm sewer system is acting as a combined sewer system. In these cases, consideration should be given to the economic and practical advantages of designating the storm sewer system a combined sewer and applying end-of-pipe treatment to the entire system.

A SWCA program needs to be periodically updated. Updating is especially important upon the introduction of new raw materials or changes in processes at the site.

It is also important to establish parameters for measuring the success of the correction program. If results do not meet expectation, then reassessment and appropriate changes to the correction program should be made.

COSTS

Costs for the initial assessment may be high. However, by pinpointing high potential areas or activities a SWCA program may reduce overall costs associated with a complete BMP implementation program. The costs associated with an assessment program for stormwater are small when compared to or a part of a larger overall hazardous waste site assessment.

ENVIRONMENTAL IMPACT

A comprehensive SWCA program can eliminate pollution sources that can significantly impair receiving water quality.

REFERENCES

1. U.S. EPA, Stormwater Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices, September 1992.

2. U.S. EPA, NPDES Best Management Practices Guidance Document, June 1981.

3. Pitt, Robert, Barbe, Donald; Adrian, Donald, and Field, Richard, Investigation of Inappropriate Pollutant Entries into Storm Drainage System -- A User's Guide, U.S. EPA, Edison, New Jersey, 1992.

This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC, 20460.

STORM WATER BMP: VEGETATIVE COVERS

DESCRIPTION

This Best Management Practice (BMP) involves preserving existing vegetation or revegetating disturbed soil as soon as possible after land disturbance activities in order to control erosion and dust. Vegetative covers include sod, temporary and permanent seeding and other vegetative covers, as well as preservation of existing vegetation. Sod is a strip of permanent grass cover placed over disturbed areas to provide an immediate and permanent turf that both stabilizes the soil surface and eliminates sediment due to erosion, mud, and dust. Temporary vegetative cover involves planting grass seed immediately after rough grading to provide protection until establishment of final cover. Permanent vegetative cover is the establishment of perennial vegetation in disturbed areas. Preservation of natural vegetation (existing trees, vines, bushes, and grasses) provides a natural buffer zone during land disturbance activities.

Vegetative covers provide dust control and a reduction in erosion potential by increasing infiltration, trapping sediment, stabilizing the soil, and dissipating the energy of hard rain. Application of mulch may be required for seeded areas. Mulch is the application of plant residues or other suitable materials to the soil surface to protect the soil surface from rain impact and the velocity of stormwater runoff.

APPLICATIONS

Vegetative covers are applicable to all land uses. Soils, topography, and climate will be determinants in the selection of appropriate tree, shrub, and ground cover species. Local climatic conditions determine the appropriate time of year for planting. Temporary seeding should be performed on areas disturbed by construction left exposed for several weeks or more. Permanent seeding and planting is appropriate for any graded or cleared area where long-lived plant cover is desired. Some areas where permanent seeding is especially important are filter strips, buffer areas, vegetated swales, steep slopes, and stream banks. Design criteria for vegetative covers is included in Table 1 below.

LIMITATIONS

Limitations of vegetative covers as a BMP include:

- The establishment of vegetative covering must be coordinated with climatic conditions for proper establishment. For example, cold climate areas have limited growing seasons and arid regions require careful selection of species.

- The key to proper performance is implementation of a maintenance program to ensure healthy vegetative covering.

PERFORMANCE

Qualitatively, vegetative covers are clearly effective in controlling dust and erosion when properly implemented. The amount of runoff generated from vegetated areas is considerably reduced and is of better quality than from unvegetated areas. However, it is not possible, based on data currently available, to quantify the water quality benefits of the vegetative coverings as a BMP.

TABLE 1; DESIGN CRITERIA FOR VEGETATIVE COVERS

Measure	Extent and Material	Dimensions	Hydraulic	Avoid	Miscellaneous
Temporary Seeding	Place topsoil as needed to enhance plant growth. A loamy soil with an organic content of 1.5 percent or greater is preferred. Use rapid-growing annual grasses, small grains, or legumes. Apply seeds using a cyclone seeder, drill, cultipacker seeder, or hydroseeder.	Place topsoil, where needed, to a minimum compacted depth of 2 inches on 3:1 slopes or steeper; and of 4 inches on flatter slopes.	Divert channelized flow away from temporarily seeded areas to prevent erosion and scouring.	Heavy clay or organic soils as topsoil. Hand-broadcasting of seeds (not uniform), except in very small areas. Mowing temporary vegetation. High-traffic areas.	Use where vegetative cover is needed for less than 1 year. Use chisel plow or tiller to loosen compacted soils. As needed, apply water, fertilizer, lime, and mulch. Incorporate lime and fertilizer into top 4-6 inches of soil. Plant small grains 1 inch deep. Plant grasses and legumes 1/2-inch deep.
Permanent Seeding	Place topsoil as needed to enhance plant growth. A loamy soil with an organic content of 1.5 percent or greater is preferred. Where possible, use low maintenance local plant species. Apply seeds using a cyclone seeder, drill, cultipacker seeder, or hydroseeder.	Apply mulch to slopes 4:1 or steeper, if soil is sandy or clayey or if weather is excessively hot or dry. Place topsoil where needed.	Divert channelized flow away from seeded areas to prevent erosion and scouring.	Heavy clay or organic soils as topsoil. Hand-broadcasting of seeds (not uniform), except in very small areas. High traffic areas.	Use chisel plow or tiller to loosen compacted soils. As needed, apply water, fertilizer, lie, and mulch. Incorporate lime and fertilizer into top 4-6 inches of soil. Plant small grains 1 inch deep. Plant grasses and legumes 1/2-inch deep.

SOURCE: Reference 1.

TABLE 1: DESIGN CRITERIA FOR VEGETATIVE COVERS (Continued)

Measure	Extent and Material	Dimensions	Hydraulic	Avoid	Miscellaneous
Mulching	Prefer Organic mulches such as straw (from wheat or oats), wood chips, and shredded bark. Commercial mats and fabrics may also be very effective. Chemical soil stabilizers or binders are less effective, but may be used to tack wood fiber mulches.	Application rates (per acre): straw, one to two tons; wood chips, five to six tons; wood fiber, 0.5 to one ton; bark, 35 cubic yards; asphalt (spray), 0.10 gallon per square yard. After spreading much, less than 25 percent of the ground surface should be visible.	--	--	Mulch may be applied by machine or by hand. Chemical mulches and wood fiber mulches, when used alone, often do not provide adequate soil protection. Use nets or mats in areas subject to water flow. Anchor mulch by punching into soil, or by applying chemical agents, nets, or mats. ?Secure nets and mats with 6 inches or longer. No. 8 gauge or heavier, wire staples placed at 3-foot intervals

SOURCE. Reference 1.

TABLE 1: DESIGN CRITERIA FOR VEGETATIVE COVERS (Continued)

Measure	Extent and Material	Dimensions	Hydraulic	Avoid	Miscellaneous
Sodding	Sod should be machine-cut at a uniform thickness of 1/2 to 2 inches.	--	In waterways, select plant types able to withstand design flow velocity.	Gravel or nonsoil surfaces. Unusually wet or dry weather. Frozen soils. Mowing for at least two to three weeks.	Prior to laying sod, clear soil surface of debris, roots, branches, and stones bigger than 2 inches in diameter. Sod should be harvested, delivered, and installed within 36 hours. Lay sod with staggered joints along the contour. Lightly irrigate soils before sod placement during dry or hot periods. After placement, roll sod and wet soil to a depth of 4 inches. On slopes steeper than 3:1, secure sod with stakes. In waterways, lay sod perpendicular to water flow. Secure sod with stakes, wire, or netting.
Preservation of Natural Vegetation	Careful planning is required prior to start of construction.	Wherever possible, maintain existing contours.	Maintain existing hydraulic characteristics.	Activities within the drop line of trees. Concentrating flows at new locations.	Preservation of vegetation should be planned before any site disturbance begins. Proper maintenance is vitally important. Clearly mark areas to be preserved.

SOURCE: Reference 1.

MAINTENANCE

Areas should be checked following each rain to ensure that seed, sod, and mulch have not been displaced. Staking the sod or netting for seeded areas may be required.

Newly sodded areas need to be inspected frequently for the first new months to ensure the sod is maturing. Failures may be due to improper conditioning of the subsoil, lack of irrigation, improper staking, or improper placement of sod pieces.

Newly seeded areas need to be inspected frequently for the first few months to ensure the grass is growing at a proper rate and density. If the seeded area is damaged, determine the cause of the damage before repeating seed bed preparation and seeding procedures.

Once a vegetative cover has been established, it is important to water the sod frequently and uniformly. If the grass is to be mowed, keep grass to a height appropriate for the species selected and the intended use. Occasional soil tests should be collected and analyzed to determine if the soil is appropriately fertilized. Weed control should only be done if absolutely required. Spot seeding should be done to small and damaged areas.

COSTS

Cost estimates for sodding, seeding, and mulching are provided in Table 2 below. These costs were developed by the Southeastern Wisconsin Regional Planning Commission (1991). Please note that costs very depending on local conditions.

TABLE 2: INSTALLATION COSTS

Description	Unit	Material	Labor	Equip-ment	Indirect Cost	Total Cost	Year of Cost	Comments
Sodding								
Level								
>400 square yards	Square yard	$0.98	$0.85	$0.17	$0.56	$2.56	January 1989	--
100 square yards	Square yard	1.36	1.07	0.22	0.70	3.35		
50 square yards	Square yard	1.95	1.14	0.23	0.80	4.12		
Slopes								
400 square yards	Square yard	1.03	1.19	0.24	0.72	3.18		
Seeding								
Mechanical Seeding	Acre	$410.00	$435.00	$165.00	$290.00	$1,300.00	January 1989	--
	Square yard	0.08	0.09	0.03	0.06	0.26		
Fine Grade/Seed	Square yard	0.15	0.85	0.17	0.48	1.65		Includes fertilizer and lime
Push Spreader								
Grass Seed	1,000 square feet	$8.60	$0.67	$0.26	$1.22	$10.75	January 1989	--
Limestone	1,000 square feet	2.05	0.67	0.26	0.58	3.56		
Fertilizer	1,000 square feet	5.40	0.67	0.26	0.92	7.25		
Level Areas	Acre	578.21	149.30	80.63	251.00	1,059.14	Mid-1988	--
Sloped Areas	Acre	578.21	238.88	129.00	328.75	1,274.84		
Mulching								
Hay	Acre	$255.76	$74.65	$40.31	$118.50	$489.22	Mid-1988	--
	Square yard	--	--	--	--	0.58	1983	Average
						0.25-1.00		Typical range

NOTE: Total cost includes operation and maintenance, taxes, insurance and other contingencies.

SOURCE: Modified from Reference 4.

ENVIRONMENTAL IMPACTS

None for proper installation of vegetative covers. However, care must be taken to avoid contamination of run off and ground water from over use of fertilizers, weed control herbicides and other hazardous chemicals.

REFERENCES

1. Hennepin Conservation District, Minnesota, Erosion and Sediment Control Manual, 1989.

2. Metropolitan Washington Council of Governments, Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs, 1987.

3. Minnesota Pollution Control Agency, Protecting Water Quality in Urban Areas, 1989.

4. Southeastern Wisconsin Regional Planning Commission, Costs of Urban Nonpoint Source Water Pollution Control Measures, Technical Report No. 31, June 1991.

5. U.S. EPA, Stormwater Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices, September,1992.

6. Washington State Department of Ecology, Stormwater Management Manual for the Puget Sound Basin, February 1992.

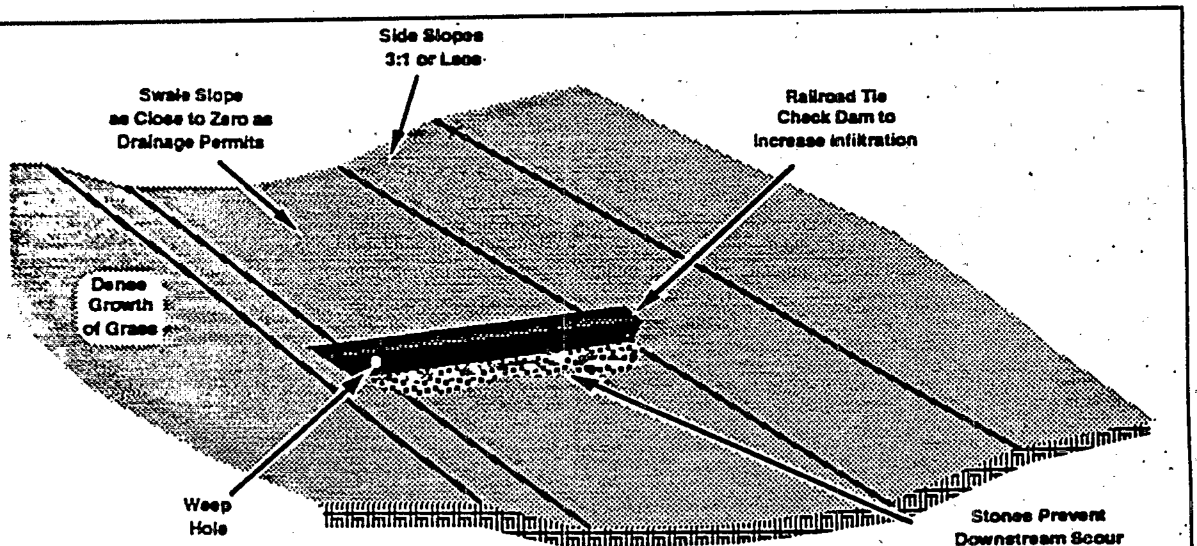
This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC, 20460.

STORM WATER BMP: VEGETATED SWALES

DESCRIPTION

Vegetated swales are natural or man made, broad, shallow channels with a dense stand of vegetation covering the side slopes and main channel. Vegetated swales trap particulate pollutants (total suspended solids and trace metals), promote infiltration, and reduce the flow velocities of stormwater runoff. Figure 1 below illustrates an example of a vegetated swale.

Vegetated swales can serve as an integral part of an area's minor stormwater drainage system by replacing curbs and gutters and storm sewer systems in low-density residential, industrial, and commercial areas. The swale's advantages over a storm sewer system generally include reduced peak flows, increased pollutant removal, and lower capital costs. However, vegetated swales typically have a limited capacity to accept runoff from large storm, since high velocity flows can cause erosion of the swale or damage the vegetated cover.



SOURCE: Reference 1.

FIGURE 1: EXAMPLE OF A VEGETATED SWALE

COMMON MODIFICATIONS

The effectiveness of vegetated swales can be enhanced by adding check dams approximately every 50 feet to increase storage, decrease flow velocities, and promote particulate settling. Structures to skim off floating debris may also be added. Incorporating vegetated filter strips parallel to the top of the channel banks can also help to treat sheet flows entering the swale.

CURRENT STATUS

Vegetated swales are relatively easy to design and incorporate into a site drainage plan. While swales are not generally used as a stand alone Stormwater Best Management Practice (BMP), they are very effective when used in conjunction with other BMP's such as wet ponds, infiltration strips, wetlands, etc.

APPLICATIONS

Vegetated swales can be used in all regions of the country where climate and soils permit the establishment and maintenance of a dense vegetative cover. The suitability of a vegetated swale at a particular site depends on the area, slope, and imperviousness of the contributing water shed, as well as the dimensions, slope, and vegetative covering employed in the swale system.

GENERAL LIMITATIONS

The limitations of vegetated swales include:

- Vegetated swales are generally impractical in areas with very flat grades, steep topography, or wet or poorly drained soils.
- Swales provide minimal water quantity and quality benefits when flow volumes and/or velocities are high.
- Swales may pose a potential drowning hazards, create mosquito breeding areas, and cause odor problems.
- The use of vegetated swales may be limited by the availability of land.
- Many local municipalities prohibit the use of vegetated swales if peak discharges exceed five cubic feet per second (cfs) or flow velocities are greater than three feet per second (fps).
- Vegetative swales are generally impractical in areas with erosive soils or where a dense vegetative cover is difficult to maintain.
- Certain quantitative aspects of vegetated swales are not known at this time. These include whether pollutant removal rates of swales decline with age, the effect of slope on the filtration capacity of vegetation, the benefit of check dams, and the degree to which design factors can enhance the effectiveness of pollutant removal.

PERFORMANCE

Conventional vegetated swale designs have achieved mixed results in removing particulate pollutants, such as suspended solids and trace metals. For example, three grass swales in the Washington, DC, area were monitored by the Nationwide Urban Runoff Program (NURP). NURP found no significant improvement in urban runoff quality for the pollutants analyzed. However, the weak performance of these swales was attributed to the high flow velocities in the swales, soil compaction, steep slopes, and short grass height. A Durham, NC, project monitored the performance of a carefully designed artificial swale that received runoff from a commercial parking lot. The project monitored 11 storm and concluded that particulate concentrations of heavy metals (Cu,Pb,Zn, and Cd) were reduced by approximately 50 percent. However, the swale proved largely ineffective for removing soluble nutrients. A conservative estimate is that properly designed vegetated swales may achieve a 25 to 50 percent reduction in particulate pollutants, including sediment and sediment-attached phosphorus, metals, and bacteria. Lower removal rates (less than 10 percent) can be expected for dissolved pollutants, such as soluble phosphorus, nitrate, and chloride.

The literature suggest that vegetated swales represent a practical and potentially effective technique for control of urban runoff quality. While limited quantitative performance data exists for vegetated swales, some known positive factors for pollutant removal are check dams, flatter slopes, permeable soils, dense grass cover, longer contact time, and smaller storm events. Negative factors include compacted soils, short runoff contact time, larger storm events, frozen ground, short grass heights, steep slopes, and high runoff velocities and discharge rates.

The useful life of a vegetated swale system is directly proportional to the effectiveness and frequency of maintenance. If properly designed and regularly maintained, vegetated swales can last an indefinite period of time.

DESIGN CRITERIA

Although specific quantitative performance data for vegetated swales is limited, design criteria have been established for implementation of the vegetated swales and is presented below.

- Location. Vegetated swales are typically located along property boundaries, although they can be used effectively wherever the site provides adequate space. Swales can be used in place of curbs and gutters along parking lots.

- Soil Requirements. Gravelly and coarse sandy soils that cannot easily support dense vegetation should be avoided. If available, alkaline soils and subsoils should be used to promote the removal and retention of metals. Soil infiltration rates should be greater than one-half inch per hour, therefore, care must be taken to avoid compacting the soil during construction.

- Vegetation. Fine, close-growing, water-resistant grass should be selected for use in vegetated swales. Dense vegetation maximizes water contact, improving the effectiveness of the swale system. The vegetation should be selected on the basis of pollution control objectives and the ability to thrive in the conditions present in the conditions present at the site. Some examples of vegetation appropriate for swales include reed canary grass, grass-legume mixtures, and red fescue.

- General Channel Configuration. It is recommended that a parabolic or trapezoidal cross-section with side slopes no steeper than 3:1 be used, maximizing the wetted, channel perimeter. Recommendations for longitudinal channel slopes vary within the existing literature. For example, Shuler (1987) recommends a vegetated swale slope as close to zero as drainage permits. The Minnesota Pollution Control Agency (1989) recommends that the channel slope be less than 2 percent. The Stormwater Management Manual for the Puget Sound Basis (1992) specifies channel slopes between 2 and 4 percent; slopes of less than 2 percent can be used if drain tile is incorporated into the design, and slopes greater than 4 percent can be used if check dams are placed in the channel to reduce flow velocity.

- Drainage Area. The maximum flow rate (Q) to the swale can be calculated using the Rational Formula, depending on the size of the drainage area (A), the percentage of the drainage area that is impervious (C) and the rainfall intensity (I) for the design storm.

  $$Q = CiA$$

  A typical design storm used for sizing swales is a six-month frequency, 24- hour storm event. The exact intensity must be calculated for your location and is generally available from the US Geological Survey (USGS). Swales are generally not used where the maximum flow rate exceeds 5 cfs.

- Sizing Procedures. The width of the swale can be calculated using various forms of the Manning equation. However, this methodology can be simplified to the following rule of thumb: the total surface area of the swale should be 500 square feet for each acre that drains to the swale.

  Unless a bypass is provided, the swale must be sized as both a treatment device and to pass the peak hydraulic flows. But to be most effective as a treatment device, the depth of the stormwater should not exceed the height of the grass in the swale.

Design Parameters. Based on limited research, swales can generally be designed using the following parameters:

1. Minimum grass height of 6 inches (Figure 2).

2. Maximum depth of stormwater during the design storm of 4 inches (Figure 2).

3. Maximum flow in the swale of 5 cfs.

4. Maximum velocity in the swale of 3 fps.

5. Channel slope between 2 and 5 percent.

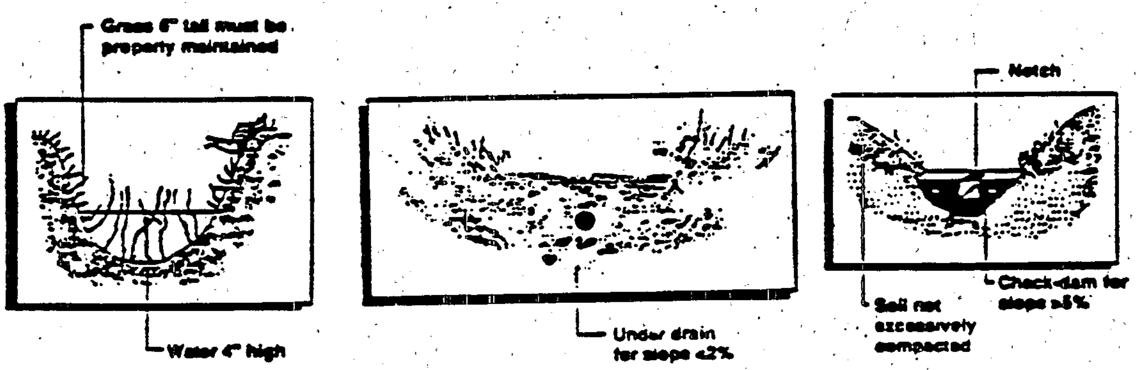
   - Slopes of less than 2 % can be used if the swale is drained to prevent ponding (Figure 2).

   - Slopes of more than 5 % can be used if check dams are placed in the swale to maintain channel velocity below 3 fps (Figure 2).

6. To provide maximum long term treatment effectiveness, the swale width should be calculated using a design flow of 0.2 cfs per acre of area draining into the swale. However, the minimum width is 18 inches.

7. If a by-pass is not provided, the channel width and/or height should be increased, if needed, to pass peak hydraulic flows.

8. In order to provide adequate treatment, the swale should have a minimum length of 200 feet. If a shorter length must be used, the width should be increased proportionally to maintain a treatment surface area of at least 500 square feet, as discussed above. However, the minimum length is 25 feet.



SOURCE: Reference 3.

FIGURE 2: DESIGN PARAMETERS

- Construction. The subsurface of the swale should be carefully constructed to avoid compaction of the soil. Compacted soil reduces the infiltration and inhibits growth of the grass. Damaged areas should be restored immediately to ensure that the desired level of treatment is maintained and to prevent further damage due to erosion of exposed soil.

- Check Dams. Check dams can be installed in swales to promote additional infiltration, increase storage, and reduce velocities. The check dam may be a railroad tie embedded into the swale with riprap placed on the downstream side of the tie to prevent a scour hole from forming. Earthen check dams are not recommended because of their potential to erode. Check dams should be installed every 50 feet if longitudinal slope exceeds 4 percent.

MAINTENANCE

The primary swale maintenance objectives are to maintain the hydraulic efficiency of the channel and maintain a dense, healthy grass cover. Maintenance activities should include periodic mowing (with grass never cut shorter than the design flow depth), Weed control, watering during drought conditions, reseeding bare areas, and clearing of debris and blockages. Cuttings should be removed from the channel and disposed in a local composting facility. Accumulated sediment should be removed periodically. Application of fertilizers and pesticides should be minimal, if required.

Research has not yet identified proper mowing strategies. However, mowings during the spring and summer should keep the grass at the 6" design height. In some commercial applications where 6" may cause an aesthetic problem the grass can be cut to 4" but the last mowing of the season should not be below 6". Mowing encourages growth thereby improving the removal of soluble pollutants. The final mowing should occur near the end of the growth season. Failure to remove the growth before the dormant season will cause a loss of pollutants back to the stormwater.

Any damage to the channel such as rutting must be repaired with suitable soil, properly tamped and seeded. The grass cover should be thick; if it is not reseeding as necessary.

Any standing water removed during the maintenance operation must be disposed to a sanitary sewer at an approved discharge location. Residuals (ie, silt, grass cuttings, etc.) must be disposed of in accordance with local or state requirements.

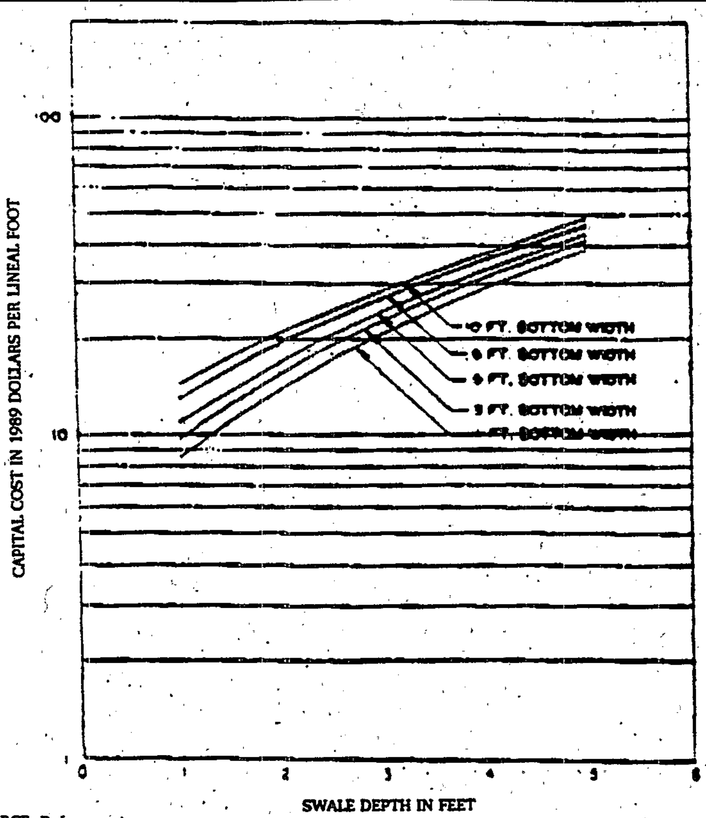
COSTS

Vegetated swales typically cost less to construct than curbs and gutters or underground storm sewers. Shuler (1987) reported that costs may vary from \$4.90 to \$9.00 per lineal foot for a 15-foot wide channel (top width).

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) reported that costs may vary from \$8.50 to \$50.00 per lineal foot depending upon swale depth and bottom width (1991). The SEWRPC cost estimates are higher than other published estimates because they include the cost of activities such as clearing, grubbing, leveling, filling, and sodding, which may not be included in many of the reported costs. Construction costs depend on specific site considerations and local costs for labor and materials. The Table 1 below shows estimates capital cost of a vegetated swale.

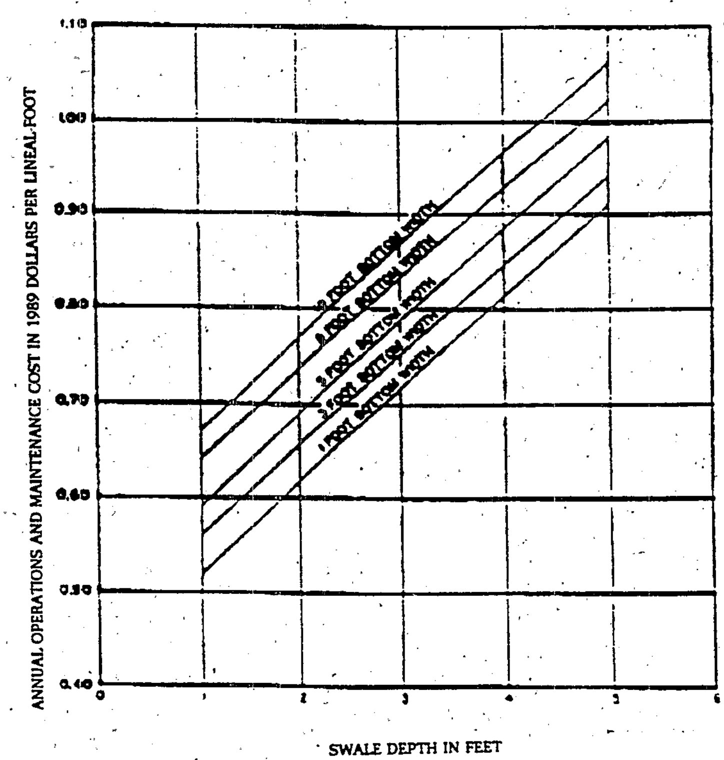
Annual costs associated with maintaining vegetated swales are approximately \$0.58 per lineal foot for a 1.5-foot deep channel, according to SEWRPC (1991). Estimated average annual operating and maintenance costs of vegetated swales can be estimated using Table 2 below.

TABLE 1: ESTIMATED CAPITAL COSTS



SOURCE: Reference 4.

TABLE 2: ESTIMATED O & M COSTS



SOURCE; Reference 4.

ENVIRONMENTAL IMPACTS

Negative environmental impacts of vegetated swales may include:

- Leaching from culverts and fertilized lawns may increase the presence of trace metals and nutrients in the runoff.
- Infiltration through the swale may affect local groundwater quality.
- Standing water in vegetated swales can result in potential safety, odor, and mosquito problems.

REFERENCES

1. U.S. EPA, A Current Assessment of Best Management Practices; Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone, December 1991.
2. Minnesota Pollution Control Agency, Protecting Water Quality in Urban Areas, 1991.
3. Shuler, Thomas R., Controlling Urban Runoff. A Practical Manual for Planning and Designing Urban BMPs, July 1987.
4. Southeastern Wisconsin Regional Planning Commission, Cost of Urban Nonpoint Source Water Pollution Control Measures, Technical Report No. 31, 1991.
5. U.S. EPA, Stormwater Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices, September 1992.
6. U.S. EPA, Results of the Nationwide Urban Runoff Program, December 1983.
7. Washington State Department of Ecology, Stormwater Management Manual for the Puget Sound Basin, Februaru 1992.

This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC, 20460.

STORM WATER BMP: VISUAL INSPECTIONS

DESCRIPTION

Visual inspection is the process by which members of a Stormwater Pollution Prevention Team (SWPPT) visually inspects stormwater discharge from material storage and outdoor processing areas to identify contaminated stormwater and its possible sources.

An example of a visual inspection is examination within the first hour of a storm event that produces significant stormwater runoff for the presence of floating and suspended materials, oil and grease, discolorations, turbidity, odor, or foam. Another example would be to examine a raw materials storage area where materials are stored in 55-gallon drums and look for leaks, discolorations, or other abnormalities that may cause a pollutant to contaminate stormwater runoff.

CURRENT STATUS

The U.S. EPA has recognized visual inspections as a baseline Best Management Practice (BMP) for over 10 years. Its implementation across the country, however, has been sporadic. Stormwater Pollution Prevention Plan (SWPPP) development will increase implementation of visual inspections in the future as facility management recognizes it to be an effective BMP from a water quality and cost savings perspective.

LIMITATIONS

Limitations associated with visual inspections include:

- Inspections are limited to those areas clearly visible to the human eye
- Visual inspections need to be performed by qualified personnel
- Lack of a corporate commitment to actively implement inspections on a routine basis
- Inspectors need to be properly motivated to perform a thorough visual inspection.

PERFORMANCE

The performance of visual inspections as an effective tool in reducing stormwater runoff contamination is highly variable and dependent upon site-specific parameters such as industrial activity occurring at the facility, maintenance procedures, and employees. Currently there is no quantitative data regarding the effectiveness of visual inspections as a BMP.

DESIGN CRITERIA

Visual inspections should be performed routinely for the presence of non-stormwater discharges. Flows during a dry period should be observed to determine the presence of any dry weather flows, stains, sludges, odors, and other abnormal conditions.

Visual inspections should be made of all stormwater discharge outlet locations during the first hour of a storm event that produces a significant amount of stormwater runoff. In geographic locations with a high frequency of storm events, inspections should be performed at least once per month. Inspection for the presence of floating and suspended materials, oil and grease, discolorations, turbidity, foam, and odor should be performed.

The inspection frequency interval is a key design criterion in a visual inspection program. To determine the inspection frequency, experienced personnel should evaluate the causes of previous incidents and assess the probable risks for occurrence in the future. Conditions in the stormwater discharge permit may also dictate inspection frequency.

Another key design criterion is proper record keeping of an inspection. Record keeping should include the date of the inspection, the names of the personnel who performed the inspection, and the observations made during the inspection. Records should be forwarded to appropriate personnel through an internal reporting system. Remedial modifications to a facility can then be implemented based on documented inspections.

Visual inspections of a facility should focus on the following key areas:

- Storage facilities
- Transfer pipelines
- Loading and unloading areas
- Pipes, pumps, valves, and fittings
- Internal and external inspection for tank corrosion
- Wind blowing of dry chemicals
- Tank support or foundation deterioration
- Deterioration of primary or secondary containment facilities
- Damage to shipping containers
- Wind blowing of dry chemicals and dust particles
- Integrity of stormwater collection system
- Leaks, seepage, and overflows from sludge and waste disposal sites

IMPLEMENTATION

A visual inspection BMP program should be incorporated within the facility's record keeping and internal reporting BMP structure. Estimates of outfall flow rates, and noting the presence of oil sheens, floatables, coarse solids, color, odors, etc. will probably be the most useful indicators of potential problems. Specific parameters to look for in completing a visual inspection include:

- Odor--The odor of a discharge can vary widely and sometimes directly reflects the source of contamination. Industrial discharges will often cause the flow to smell like a particular spoiled product, oil, gasoline, specific chemical, or solvent. As an example, for many industries, the decomposition of organic wastes in the discharge will release sulfide compounds into the air above the flow in the sewer, creating an intense smell of rotten eggs. In particular, industries involved in the production of meats, dairy products, and the preservation of vegetables or fruits, are commonly found to discharge organic materials into storm drains. As these organic materials spoil and decay, the sulfide production creates this highly apparent and unpleasant smell. Significant sanitary wastewater contributions will also cause pronounced and distinctive odors.

- Color--Color is another important indicator of inappropriate discharges, especially from industrial sources. Industrial discharges may be of any color. Dark colors, such as brown, gray, or black, are most common. For instance, the color contributed by meat processing industries is usually a deep reddish-brown. Paper mill wastes are also brown. In contrast, textile wastes are varied. Other intense colors, such as plating-mill wastes, are often yellow. Washing of work areas in cement and stone working plants can s\cause cloudy discharges. Potential sources causing various colored contaminated waters from industrial areas can include process waters (slug or continuous discharges), equipment and work area cleaning water discharged to floor drains, spills during loading operations (and subsequent washing of the material into the storm drains).

- Turbidity--Turbidity of water is often affected by the degree of gross contamination. Industrial flows with moderate turbidity can be cloudy, while highly turbid flows can be opaque. High turbidity is often a characteristic of undiluted industrial discharges, such as those coming from some continual flow sources, or some intermittent spills. Sanitary wastewater is also often cloudy in nature.

- Floatable matter--A contaminated flow may also contain floatables (floating solids or liquids). Evaluation of floatables often leads to the identity of the source of industrial or sanitary wastewater pollution, since these substances are usually direct products or byproducts of the manufacturing process, or distinctive of sanitary wastewater. Floatables of industrial origin may include substances such as animal fats, spoiled food products, oils, plant parts, solvents, sawdust, foams, packing materials, or fuel, as examples.

- Deposits and Stains--Deposits and stains (residue) refer to any type of coating which remains after a non-stormwater discharge has ceased. They will cover the area surrounding the stormwater discharge and are usually of a dark color. Deposits and stains often will contain fragments of floatable substances and, at times, take the form of a crystalline or amorphous powder. These situations are illustrated by the grayish-black deposits that contain fragments of animal flesh and hair which often are produced by leather tanneries, or the white crystalline powder which commonly coats sewer outfalls due to nitrogenous fertilizer wastes.

- Vegetation--Vegetation surrounding a stormwater discharge may show the effects of the wastewater. Industrial pollutants will often cause a substantial alteration in the chemical composition and Ph of the discharge water. This alteration will affect plant growth, even when the source of contamination is intermittent. For example, decaying organic materials coming from various food product wastes would cause an increase in plant life. In contract, the discharge of chemical dyes and inorganic pigments from textile mills could noticeably decrease vegetation, as these discharges often have a very acidic Ph. In either case, even when the cause of industrial pollution is gone, the vegetation surrounding the discharge will continue to show the effects of the contamination.

  In order to accurately judge if the vegetation surrounding a discharge is normal, the observer must take into account the current weather conditions, as well as the time of year in the area. Thus, flourishing or inhibited plant growth, as well as dead and decaying plant like, are all signs of pollution or scouring flows when the condition of the vegetation just beyond the discharge disagrees with the plant conditions near the discharge. It is important not to confuse the adverse effects of high stormwater flows on vegetation with highly toxic flows. Poor plant growth could be associated with scouring flows occurring during storms.

Structural Damage--Structural damage is another readily visible indication of industrial discharge contamination. Cracking, deterioration, and spalling of concrete or peeling of surface paint, occurring at an outfall are usually caused by severely contaminated discharges, usually of industrial origin. These contaminants are usually very acidic or basic in nature. For instance, primary metal industries have a strong potential for causing structural damage because their batch dumps are highly acidic. Poor construction, hydraulic scour, and old age may also adversely affect the condition of structures.

Implementation of visual inspections should be assigned to qualified staff such as maintenance personnel or environmental engineers. Figure 1 provides a sample visual evaluation worksheet which can be used to record the results of the inspections.

Outfall # ______ Photograph # ______ Date: __________

Location: ______________________________

Weather: air temp.: ___ °C rain: Y N sunny cloudy

Outfall flow rate estimate: ____ L/sec

Known industrial or commercial uses in drainage area? Y N
describe: ______________________________

PHYSICAL OBSERVATIONS:

Odor: none sewage sulfide oil gas rancid-sour other:_____

Color: none yellow brown green red gray other:______

Turbidity: none cloudy opaque

Floatables: none petroleum sheen sewage other:______ (collect sample)

Deposits/stains: none sediment oily describe:_______ (collect sample)

Vegetation conditions: normal excessive growth inhibited growth
extent: ______________________________

Damage to outfall structures:
identify structure: ______________________________
damage: none / concrete cracking / concrete spalling / peeling paint / corrosion
other damage: ______________________________
extent: ______________________________

SOURCE: Reference 4.

FIGURE 1: VISUAL INSPECTION WORKSHEET

MAINTENANCE

Maintenance involved with visual inspections as a BMP include developing a schedule for performing visual inspections and follow-up to make sure the inspections are performed on schedule. Continual record updates need to be performed with each inspection, and properly routed through the internal reporting structure of a SWPPT.

COSTS

Costs are those associated with direct labor and overhead costs for staff hours. Annual costs can be estimated using the example in Table 1 below. Figure 2 can be used as a worksheet to calculate the estimated annual cost for implementing a visual inspection program.

TABLE 1: EXAMPLE OF ANNUAL VISUAL INSPECTION PROGRAM COSTS

Title	Quantity		Avg. Hourly Rate ($)		Overhead* Multiplier		Estimated Yearly Hours on SW Training		Est. Annual Cost ($)
Stormwater Engineer	1	x	15	x	2.0	x	20	=	600
Plant Management	5	x	20	x	2.0	x	10	=	2,000
Plant Employees	100	x	10	x	2.0	x	5	=	10,000
					TOTAL ESTIMATED ANNUAL COST				$12,600

Note: Defined as a multiplier (typically ranging between 1 and 3) that takes into account those costs associated with payroll expenses, building expenses, etc.

SOURCE: EPA

Title	Quantity		Avg. Hourly Rate ($)		Overhead Multiplier		Estimated Yearly Hours on SW Training		Est. Annual Cost ($)	
________	____	x	____	x	____	x	____	=	____	(A)
________	____	x	____	x	____	x	____	=	____	(B)
________	____	x	____	x	____	x	____	=	____	(C)
________	____	x	____	x	____	x	____	=	____	(D)
					TOTAL ESTIMATED ANNUAL COST (Sum of A+B+C+D)				____	

SOURCE: Reference 3.

FIGURE 2: SAMPLE ANNUAL VISUAL INSPECTION PROGRAM COST WORKSHEET.

ENVIRONMENTAL IMPACTS

Visual inspections is an effective way to identify a variety of problems. Correcting these problems can have a significant impact on improving water quality in the receiving water.

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This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC, 20460.

In order for the Municipal Technology Branch to be effective in meeting your needs, we need to understand what your needs are and how effectively we are meeting them. Please take a few minutes to tell us if this document was helpful in meeting your needs, and what other needs you have concerning wastewater treatment, water use efficiency, or reuse.

Indicate how you are best described:

[ ] concerned citizen	[ ] local official	[ ] researcher
[ ] consultant	[ ] state official	[ ] student
[ ] other ____________		

Name and Phone No. (optional)____________________________

[ ] This document is what I was looking for.

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[ ] The document was especially helpful in the following ways:

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[ ] I was unable to meet my need with this document. What I really need is:

[ ] I found the following things in this document which I believe are wrong:

[ ] What other types of technical assistance do you need?

____

____

We thank you for helping us serve you better. To return this questionnaire, tear it out, fold it, staple it, put a stamp on it and mail it. Otherwise, it may be faxed to 202-260- 0116

EPA MTB
Office of Wastewater Enforcement & Compliance
MUNICIPAL TECHNOLOGY BRANCH

MUNICIPAL WASTEWATER MANAGEMENT FACT SHEETS:
STORM WATER BEST MANAGEMENT PRACTICES

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ADDENDUM TO

MUNICIPAL WASTEWATER MANAGEMENT FACT SHEETS
STORM WATER BEST MANAGEMENT PRACTICES
EPA-832-F-93-013

September, 1994

Prepared by the Municipal Technology Branch
United States Environmental protection Agency
Office of Water, Washington, D.C.

PREFACE

This document is part of a series of municipal wastewater management fact sheets. These fact sheets are intended to serve a wide audience including: the consulting engineer who is looking for basic technical information on technologies; the municipal engineer who must understand these technologies well enough to evaluate the assets and limitations; the municipal official who must sell the technologies as part of a comprehensive pollution prevention program; the state regulator who must approve the technologies used to meet permit requirements; and ultimately the citizen who must understand the importance of preventing pollution of the Nation's waters.

The material presented is guidance for general information only. This information should not be used without first obtaining competent advice with respect to its suitability to any general or specific application. References made in this document to any specific method, product or process does not constitute or imply an endorsement, recommendation or warranty by the U.S. Environmental Protection Agency.

Municipal Wastewater Management Fact Sheets are divided into several sets: Wet Weather Flow Management Practices; Innovative and Alternative Technologies; Biosolids Technologies and Practices; Wet Weather Technologies; Water Conservation, etc. Each set is published separately starting with Storm Water Best Management Practices, September, 1993 (EPA 832-F-93-013). Updates to this set of fact sheets and development of additional sets is dependent upon continued resources being available.

ADDENDUM

TABLE OF CONTENTS

INTRODUCTION

Storm water runoff is part of a natural hydrologic process. However, human activities, particularly urbanization, can alter drainage patterns and add pollution to the rain water and snow melt that runs off the earth's surface and enters our Nation's rivers, streams, lakes, and coastal waters. A number of recent studies have shown that storm water runoff is a major source of water pollution as indicated by a decline in fish population and diversity, beach closings or restrictions on swimming and other water sports, bans on consumption of fish and shellfish and other public health concerns. These conditions limit our ability to enjoy many of the benefits that our Nation's waters provide.

In response to this problem, the States and many municipalities have been taking the initiative to manage storm water more effectively. In acknowledgement of these storm water management concerns, the U.S. Environmental Protection Agency (EPA) has undertaken a wide variety of activities, including providing technical assistance to States and municipalities to help them improve their storm water management programs.

This addendum contains fact sheets on storm water best management practices (BMPs). However, many are not stand alone BMPs, but are most effective when combined with other BMPs in a comprehensive storm water management plan. These BMPs are suitable for both municipal and industrial applications and can be used to supplement other EPA guidance documents such as **Storm Water Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices (EPA 832-R-92-006)** and **Storm Water Management for Construction Activities: Developing Pollution Prevention Plans and Best Management Practices (EPA 832-R-92-005)** as well as other State or local guidance.

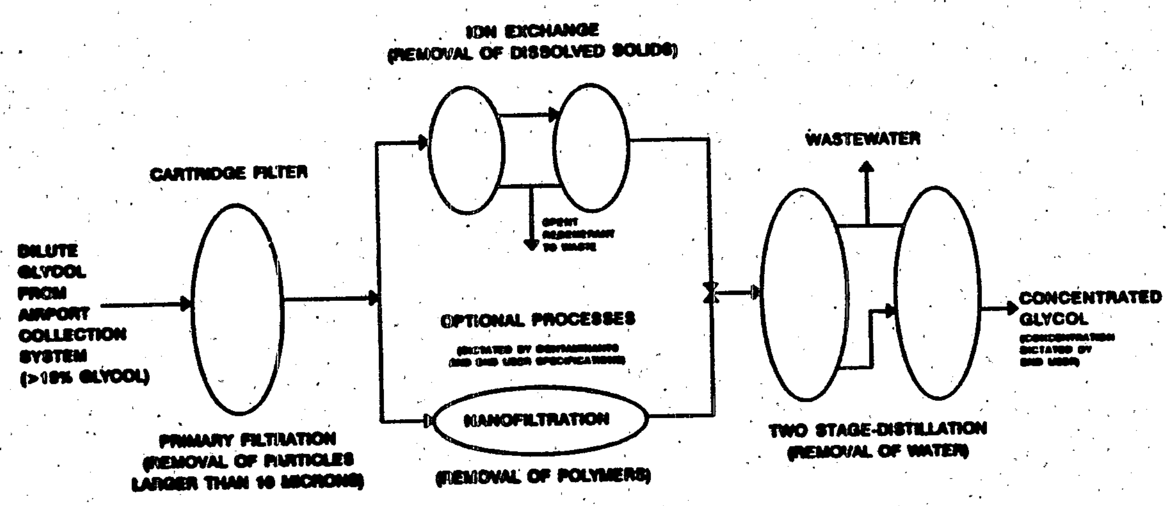
In order to better serve our customers and identify additional information needs, a short questionnaire is included at the end of this document. Please take a few minutes to tell us if the information in this addendum was helpful in meeting your needs and what other needs you have concerning storm water management. Responses can be mailed to the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC, 20460 or faxed to (202) 260-0116.

STORM WATER BMP: AIRPLANE DEICING FLUID RECOVERY SYSTEMS

MTB
Office of Wastewater Management
MUNICIPAL TECHNOLOGY BRANCH

DESCRIPTION

Ethylene or propylene glycol recovery is accomplished by a three-stage process typically consisting of primary filtration, contaminant removal via ion exchange or nanofiltration, and distillation as shown in Figure 1 below. The process technologies involved in glycol recovery have been proven in other industries and are now being applied to spent airplane deicing fluid (ADF).



SOURCE: Reference 3

FIGURE 1: TYPICAL AIRPLANE DEICING FLUID RECOVERY SYSTEM

The purpose of the primary filtration step is to remove entrained suspended solids from contact with the aircraft and pavement from the used ADF. The suspended solids must be removed to avoid plugging of downstream equipment and heat exchangers. Primary filtration is defined as the removal of solids greater than 10 micron in size. Primary filters employed by ADF systems may be polypropylene cartridge or bag filters. Ion exchange may be employed to remove dissolved solids such as chlorides and sulfates. Ion exchange removes ions from an aqueous solution by passing the wastewater through a solid material (called ion exchange resin) which accepts the unwanted ions, while giving back an equivalent number of desirable ions from the resin. Nanofiltration may be employed to remove polymeric additives. Nanofiltration systems are pressure-driven membrane operations that use porous membranes for the removal of colloidal material.

Colloidal material and polymeric molecules with molecular weights in excess of 500 are normally removed by nanofilters. The requirement to remove polymer additives is dictated by the specifications of the end user of the recovered ADF product.

The key process step in the overall ADF recycling system is distillation. Distillation is defined as the separation of more volatile materials (in this case, water) from less volatile materials (glycol) by a process of vaporization and condensation. Distillation is capable of recovering volatiles with little degradation, which is an important advantage in this application where the recovered product can be sold or recycled. Product purity of any desired level can theoretically be obtained by distillation, however in some cases the processing costs may be prohibitive. In most ADF applications, the separation of water from either a water-ethylene glycol or a water-propylene glycol mixture of ADF, employs a two stages of distillation process. This will typically, remove enough water to produce a recovered ADF with a minimum of a 50% glycol content. The requirement glycol concentration is dictated by the specifications of the end user of the recovered ADF product.

COMMON MODIFICATIONS

The details of the distillation process that each vendor employs are proprietary. Design variables include temperature; distillation column design (number of stages, type of packing, size) and reflux ratio. Batch distillation systems are generally employed due to the variation in the composition of the influent and the irregular supply of the feed. Secondary filtration and ion-exchange stages vary with the quality of the influent feed and the specifications of the end-user. The temperature of distillation also varies between ethylene glycol and propylene glycol recovery applications.

CURRENT STATUS

This fact sheet contains general information only, and should not be used as the basis for designing an airplane deicing fluid recovery system. While the basic technologies used to recycle ethylene and propylene glycol are well established, actual operating experience in recycling airplane deicing fluids is limited. To date, there is only one on-site application of ADF recovery operating in the United States. This is a pilot-scale operation conducted for Continental Airlines at the Denver Stapleton Airport. Another pilot-scale ADF operation is currently being conducted in Canada at the L.B. Pearson Airport in Toronto. While, recovery systems are proposed for the St. Louis, Missouri Airport and the Indianapolis, Indiana airport, these systems are not in operation. There are also three ADF recovery systems in operation at airports in Europe: Lulea, Sweden; Oslo, Norway; and Munich, Germany.

There are currently three vendors actively designing, testing or marketing ADF recovery systems for use on-site at airports in North America: DeIcing Systems (DIS), Glycol Specialists, Inc. (GSI), and Canadian Chemical Reclaiming (CCR). There are also a number of chemical waste service companies that will provide off-site processing for spent glycol for other industries. The technology and process applications of ADF are evolving rapidly. The equipment manufacturers and the airport operators should be contacted for the current state of the art information.

APPLICATIONS

Ethylene or propylene glycol recovery systems are generally applicable at any airport that collects ADF with a minimum concentration of approximately 15% glycol. Spent ADF mixtures with lower glycol content are generally impractical to recover via distillation, without expensive preconcentration steps such as reverse osmosis. Dilute streams are typically discharged to municipal wastewater treatment plants, if permitted, treated by oxidation to destroy the organics prior to direct discharge, or hauled away be a chemical waste contractor. A number of other BMPs such as water quality inlets and oil\water separators are being tested to demonstrate their ability and reliability to concentrate dilute streams.

LIMITATIONS

In order for the ADF to be recovered or regenerated, it must first be collected at the airport. The implementation of ADF collection must respond to the unique requirements of each airport. The feasibility of glycol recovery is dependent on the ability of the collection system to contain a relatively concentrated waste stream without significant contamination by other storm water components. Since distillation is an energy intensive process, it is generally not cost effective to distill and recycle waste glycol solutions at low concentrations (< 15%). However, individual airports may have to collect and recover lower concentrations of waste glycol solutions to satisfy requirements of their storm water NPDES permit. Remote or centralized deicing with the containment and collection of used glycol is one method for collecting a more concentrated used glycol. However, centralized deicing systems may be impractical for all but the largest airport operations due to their cost and physical size. For established airports, a switch to centralized deicing systems would present a number of operational and logistical problems. In lieu of a centralized facility, used glycol can be collected via vacuum trucks and fluid collections containers that siphon glycol from runway aprons. Roller sponge devices have been employed at the Toronto Airport with mixed results due to uneven surfaces.

Mixtures of ethylene and propylene glycols cannot be recovered effectively in a single batch process because the technology currently available cannot cost effectively separate the two glycols. While there is a market for either recovered ethylene glycol or propylene glycol, there is little demand for a recovered blend of both glycols by end users. In order to recover either ethylene or propylene glycol from spent ADF, an airport must use one or the other, or isolate application and runoff areas. Treated separately, each type of water-glycol mixture can then be recovered effectively via the distillation process.

DESIGN CRITERIA

There area number of important criteria that must be determined in order to properly design an ADF system. Table 1 below list some of the key criteria. Storage and handling of process chemicals, energy requirements, and disposal of spent chemicals and residuals generated in the recovery process must also be carefully considered. Other factors such as site drainage, weather patterns, water quality requirements, state and local restrictions, marketability of the recovered product, etc., will also influence the final design of the system.

Sodium hydroxide (NaOH) and hydrochloric acid (HCL) are required for regeneration of the ion exchange process unit. As a part of the recertification process, wetting agent and a corrosion inhibitor must be added to the recovered product prior to reuse as airplane deicing fluid. While recertification and reuse od recovered airplane deicing fluids is practiced in Europe, the Federal Aviation Administration (FAA) currently has no recertification guideline for reuse of recovered ADF in the United States. Care should be taken when handling these chemicals to avoid contact with skin. Eye protection should also be worn.

For the most part, energy requirements are dependent on the waste stream glycol concentration of the fluid to be recycled and the purity required by the end user. Recovery by distillation is energy-intensive, with nominal energy requirements being about 5.81×10^5 to 2.79×10^8 J/kg of feed (250 to 1200 BTU/lb of feed). As the technology is refined and as operating experience grows, these costs should decrease.Flush and spent

TABLE 1: KEY CRITERIA FOR DESIGNING AN AIRPLANE DEICING FLUID RECOVERY SYSTEM

- **Deicing Fluid Data**
  - Type
  - Concentration
  - Total consumption per season
  - Total consumption per peak-day
  - Average consumption per aircraft

- **Airport Operations Data**
  - Flights per day
  - Peak Traffic Periods

- **Length of deicing season**
  - Number of deicing days per season
  - Future traffic extension plans

- **Spent Fluid Data**
  - Volume generated
  - Glycol concentration
  - Contaminants

- **Reuse Specifications**
  - Glycol concentration
  - Acceptable impurities

SOURCE: References 10 and 11

wastewater are generated by recovery processes which employ ion-exchange systems. These fluids may be disposed of, after neutralization by addition of acids or bases, to the sanitary sewer. Spent filter cartridges may be generated in some systems and may be disposed of to landfills. Distillation condensate, with less than 1.5% glycol, is also generated and may be reused or disposed. Currently discharges to the sanitary sewer system may require permitting under local pretreatment programs.

PERFORMANCE

Three ADF recovery systems were evaluated using data provided by three vendors. In each ADF recovery system investigated, the quality of the fluid recovered was dictated by the specification objective. The data provided for the ethylene glycol recovery system at the Toronto Airport shows that the process reliably produced an effluent with a glycol content over 80%. The data from the ADF recovery system in Denver showed that high purity (98.5% glycol) can be reliably produced. The process at the Munich Airport reliably produced an effluent with a glycol content over 50%, which meets the lower end-user requirements in Europe.

COSTS

Since there are no full-scale ADF systems currently operation in the U.S., it is difficult to determine the actual construction costs. However, based on pilot study at the Denver Stapleton Airport, the total capital cost for the complete project, including deicing and anti-icing application equipment, collection piping, storage facilities, and glycol recovery system has been estimated to be between $6 and $7 million dollars. The construction costs for the ADF collection system, storage and handling facilities, piping, and recovery system has been estimated at approximately $600,000 (GSI, 1993).

The total capital cost for the new Denver International Airport, including deicing and anti-icing application pads and equipment, drainage and collection piping, storage and handling facilities, and complete glycol recovery system is currently estimated at between $20 and $25 million dollars. These costs are based on a complete package including planning, engineering design, equipment, construction and installation, start-up services and other contingencies. The construction costs for the ADF collection system, storage and handling facilities, piping, controls and instrumentation, and complete recovery system is currently estimated at approximately $5 million dollars.

The major operating expense for all ADF systems is cost of energy used in the distillation process. Other maintenance costs include flushing of filters and ion-exchange units, disposal of spent filter cartridges, process and neutralization chemical, lubrication of pumping equipment, and inspection and repairs to the distillation equipment and heat exchanger. The collection system and storage facilities will also require periodic cleaning and maintenance. Based on vary limited operating data from the pilot study at the Stapleton Airport, the cost for processing ADF with a 28 percent glycol concentration, is approximately 35 cents per gallon treated. However, this cost will vary depending on the volume treated and concentration of glycol in the waste stream. As the technology is refined and as operating experience grows, these costs should decrease.

ENVIRONMENTAL IMPACT

While the potential for volatile-organic emissions to the air is considered small, the discharges of air emissions from the distillation process through losses from condenser vents, accumulator tank vents, and storage tank vents must be considered. Ion-exchange flush and spent wastewater are generated by recovery processes may generally be discharged to the sanitary sewer. These spent byproducts may require neutralization by addition of acids or bases before discharge. Currently discharges to the sanitary sewer system may require permitting under local pretreatment programs. Spent filter cartridges may be generated in some systems. In most cases these can be disposed of in the local landfill.

Distillation condensate, with less than 1.5% glycol, is also generated and may be reused or disposed. However, release of more than 1 pound of ethylene glycol to the environment must be reported under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) requirements. The EPA currently has under review a proposal to raise the disposal limit to 5000 pounds. This proposal is expected to be promulgated as a rule in calendar year 1995. A spill prevention control and countermeasure (SPCC) plan should be developed for all ADF systems to address the handling, storage and accidental release of chemicals, regenerated products and waste byproducts.

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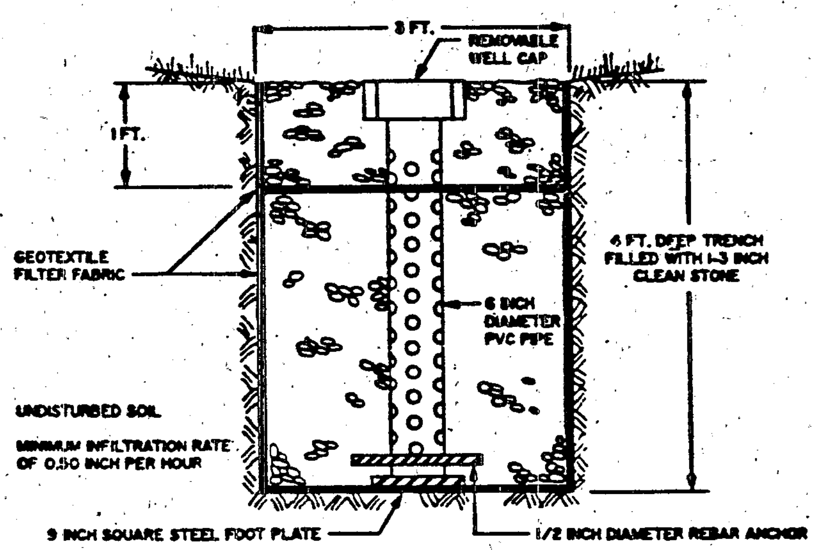
This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC, 20460

STORM WATER BMP: INFILTRATION TRENCH

MTB
Office of Wastewater Management
MUNICIPAL TECHNOLOGY BRANCH

DESCRIPTION

Infiltration trenches are used to remove suspended solids, particulate pollutants, coliform bacteria, organics and some soluble forms of metals and nutrients from storm water runoff. An infiltration trench, as shown in Figure 1 below, is an excavated trench, 3 to 12 feet deep, backfilled with stone aggregate. A small portion of the runoff, usually the first flush, is diverted to the infiltration trench, which is located either underground or at grade. The captured runoff exits the trench by infiltrating into the surrounding soils. Filtration through the soil is the primary pollutant removal mechanism. Infiltration trenches also provide groundwater recharge and preserve base-flow in nearby streams.



SOURCE: Reference 6

FIGURE 1: TYPICAL INFILTRATION TRENCH

Infiltration trenches capture and treat small amounts of runoff, but do not control peak hydraulic flows. Infiltration trenches may be used in conjunction with another best management practice (BMP), such as a detention pond, to provide both water quality control and peak flow control (Schueler, 1992, Harrington, 1989). Runoff that contains high levels of sediments or hydrocarbons (oil and grease) that may clog the trench are often pretreated with other BMPs. Examples of pretreatment BMPs include grit chambers, water quality inlets, sediment traps, swales and vegetated filter strips (SEWRPC, 1991, Harrington, 1989).

COMMON MODIFICATIONS

The infiltration trench can be modified by substituting pea gravel for stone aggregate in the top 1 foot of the trench. The pea gravel improves sediment filtering and maximizes the pollutant removal in the top of the trench. When the modified trenches become clogged, they can generally be restored to full performance by removing and replacing only of the pea gravel layer with out replacing the lower stone aggregate layers. Infiltration trenches can also be modified by adding a layer of organic material (peat) or loam to the trench subsoil. This modification appears to enhance the removal of metals and nutrient through adsorption.

CURRENT STATUS

Infiltration trenches are often used in place of other BMPs where limited land is available. Infiltration trenches are most widely used in warmer, less arid regions of the U.S. However, recent studies conducted in Maryland and New Jersey on trench performance and operation and maintenance, have demonstrated the applicability of infiltration trenches in colder climates (Lindsey, et al, 1991).

LIMITATIONS

The use of infiltration trenches may be limited by a number of factors, including type of soils, climate, and location of groundwater tables. Site characteristics, such as the slope of the drainage area, soil type, and location of the water table and bedrock, may preclude the use of infiltration trenches. The surrounding area slope should be such that the runoff is evenly distributed in sheet flow as it enters the trench. Generally, infiltration trenches are not suitable for areas with relatively impermeable soils such as clayey and silty soils or in areas with fill. The trench should be located above the water table so that the runoff can filter through the trench and into the surrounding soils and eventually into the groundwater. In addition, the drainage area should not convey heavy levels of sediments or hydrocarbons to the trench. For this reason, trenches serving parking lots should be preceded by appropriate pretreatment. Generally, trenches that are constructed under parking lots are also difficult to access for maintenance.

As with any infiltration BMP, the potential of groundwater contamination must be carefully considered, especially if the groundwater is used for human consumption or agricultural purposes. . In some cases the infiltration trench may not be suitable for sites that use or store chemicals or hazardous materials. In these areas other BMPs that do not interact with the groundwater should be considered. If infiltration trenches are selected, hazardous and toxic materials must be prevented from entering the trench. The potential for spills can be minimized by aggressive pollution prevention measures. Many municipalities and industries have developed comprehensive spill prevention control and countermeasure (SPCC) plans. These plans should be modified to include the infiltration trench and the contributing drainage area. For example, diversion structures can be used to prevent spills from entering the infiltration trench.

An additional limitation is the climate. In cold climates, trench surface may freeze, thereby preventing the runoff from entering the trench and allowing the untreated runoff to enter surface water. The surrounding soils may also freeze reducing infiltration into the soils and groundwater. However, recent studies indicate if properly designed and maintained infiltration trenches can operate effectively in colder climates. By keeping the trench surface free of compacted snow and ice and by ensuring the part of the trench is constructed below the frost line, will greatly improve the performance of the infiltration trench during cold weather.

PERFORMANCE

Infiltration trenches function similarly to rapid infiltration systems that are used in wastewater treatment. Estimated pollutant removal efficiencies from wastewater treatment performance and modeling studies are shown in Table 1 below. Based on this data, infiltration trenches can be expected to remove up to 90 percent of sediments, metals, coliform bacteria and organic matter, and up to 60 percent of phosphorus and nitrogen in the runoff (Schueler, 1987, 1992). Biochemical oxygen demand (BOD) removal is estimated to be between 70 to 80 percent. Lower removal rates for nitrate, chlorides and soluble metals should be expected especially in sandy soils (Schueler, 1992).

TABLE 1: TYPICAL POLLUTANT REMOVAL EFFICIENCY

Pollutant	Typical Percent Removal Rates
Sediment	90%
Total Phosphorus	60%
Total Nitrogen	60%
Metals	90%
Bacteria	90%
Organics	90%
Biochemical Oxygen Demand	70 - 80%

SOURCE: References 4 and 5

Pollutant removal efficiencies may be improved by using washed aggregate and adding organic matter and loam to the subsoil. The stone aggregate should be washed to remove dirt and fines before placement in the trench. The addition of organic material and loam to the trench subsoil will enhance metals and nutrient removal through adsorption.

LONGEVITY

There have been a number of concerns raised about the long term effectiveness of infiltration trench systems. In the past, infiltration trenches have demonstrated a relatively short life span with over 50 percent of the systems checked, having partially or completely failed after 5 years. A recent study of infiltration trenches in Maryland (Lindsey et al., 1991) found that 53 percent were not operating as designed, 36 percent were partially or totally clogged, and another 22 percent exhibited slow filtration. Longevity can be increased by careful geotechnical evaluation prior to construction. Soil infiltration rates and the water table depth should be evaluated to ensure that conditions are satisfactory for proper operation of an infiltration trench. Pretreatment structures, such as a vegetated buffer strip or water quality inlet, can increase longevity by removing sediments, hydrocarbons and other materials that may clog the trench. Regular maintenance including the replacement of clogged aggregate, will also increase the effectiveness and life of the trench.

DESIGN CRITERIA

Prior to trench construction, a review of the design plans may be required by state and local governments. The design plans should include a geotechnical evaluation that determines the feasibility of using an infiltration trench at the site. Soils should have a low silt and clay content and have infiltration rates greater than 0.5 inches per hour. Acceptable soil texture classes include sand, loamy sand, sandy loam and loam. These soils are within the A or B hydrologic group. Soils in the C or D hydrologic groups should be avoided. Soil survey reports published by the Soil Conservation Service can be used to identify soil types and infiltration rates. However, sufficient soil borings should always be taken to verify site conditions. Feasible sites should have a minimum of 4 feet to bedrock in order reduce excavation costs. There should also be a least 4 feet below the trench to the water table to prevent potential ground water problems. Trenches should also be located at least 100 feet up gradient from water supply wells and 100 feet from building foundations. Land availability, the depth to bedrock and the depth to the water table will determine whether the infiltration trench is located underground or at grade. Underground trenches receive runoff though pipes or channels, whereas surface trenches collect sheet flow from the drainage area.

In general infiltration trenches are suitable for drainage areas up to 10 acres (SEWRPC, 1991, Harrington, 1989). However, when the drainage area exceed 5 acres, other BMPs should be carefully considered (Schueler, 1989 and 1992). The drainage area must be fully developed and stabilized with vegetation before constructing an infiltration trench. High sediment loads from unstabilized areas will quickly clog the infiltration trench. Runoff from unstabilized areas should be diverted away from the trench until vegetation is established.

The drainage area slope determines the velocity of the runoff and also influences the amount of pollutants entrained in the runoff. Infiltration trenches work best when the up gradient drainage area slope is less than 5 percent (SEWRPC, 1991). The down gradient slope should be no greater than 20 percent to minimize slope failure and seepage.

The trench surface may consist of stone or vegetation with inlets to evenly distribute the runoff entering the trench (SEWRPC, 1991, Harrington, 1989). Runoff can be captured by depressing the trench surface or by placing a berm at the down gradient side of the trench. Underground trenches are covered with an impermeable geotextile membrane overlain with topsoil and grass.

A vegetated buffer strip (20 to 25 foot wide) should be established adjacent to the infiltration trench to capture large sediment particles in the runoff. The buffer strip should be installed immediately after trench construction using sod instead of hydroseeding (Schueler, 1987). The buffer strip should be graded with a slope between 0.5 and 15 percent so that runoff enters the trench as sheet flow. If runoff is piped or channeled to the trench, a level spreader can be installed to create sheet flow (Harrington, 1989).

During excavation and trench construction, only light equipment such as backhoes or wheel and ladder type trenchers should be used to minimize compaction of the surrounding soils. Filter fabric should be placed around the walls and bottom of the trench and 1 foot below the trench surface. The filter fabric should overlap each side of the trench in order to cover the top of the stone aggregate layer (see Figure 1). The filter fabric prevents sediment in the runoff and soil particles from the sides of the trench from clogging the aggregate. Filter fabric that is placed 1 foot below the trench surface will maximize pollutant removal within the top layer of the trench and decrease the pollutant loading to the trench bottom.

The required trench volume can be determined by several methods. One method calculates the volume based on capture of the first flush, which is defined as the first 0.5 inches of runoff from the contributing drainage area (SEWRPC, 1991). The State of Maryland (MD., 1986) also recommends sizing the trench based on the first flush, but defines first flush as the first 0.5 inches from the contributing impervious area. The Metropolitan Washington Council of Governments (MWCOG) suggests that the trench volume be based on the first 0.5 inches per impervious acre or the runoff produced from a 1 inch storm. In Washington D.C., the capture of 0.5 inches per impervious acre accounts for 40 to 50 percent of the annual storm runoff volume. The runoff not captured by the infiltration trench should be bypassed to another BMP (Harrington, 1989) if treatment of the entire runoff from the site is desired.

Trench depths are usually between 3 and 12 feet (SEWRPC, 1991, Harrington, 1989). However, a depth of 8 feet is most commonly used (Schueler, 1987). A site specific trench depth can be calculated based on the soil infiltration rate, aggregate void space, and the trench storage time (Harrington, 1989). The stone aggregate used in the trench is normally 1 to 3 inches in diameter, which provides a void space of 40 percent (SEWRPC, 1991, Harrington, 1989, Schueler, 1987).

A minimum drainage time of 6 hours should be provided, to ensure satisfactory pollutant removal in the infiltration trench (Schueler, 1987, SEWRPC, 1991). Although trenches may be designed to provide temporary storage of storm water, the trench should drain prior to the next storm event. The drainage time will vary by precipitation zone. In the Washington, D.C. area, infiltration trenches are designed to drain within 72 hours.

An observation well is recommended to monitor water levels in the trench. The well can be a 4 to 6 inch diameter PVC pipe, which is anchored vertically to a foot plate at the bottom of the trench as shown in Figure 1 above. Inadequate drainage may indicate the need for maintenance.

MAINTENANCE

Maintenance should be performed as needed. The principal maintenance objective is to prevent clogging, which may lead to trench failure. Infiltration trenches and any pretreatment BMPs should be inspected after large storm events and any accumulated debris or material removed. A more through inspection of the trench should be conducted at least annually. Annual inspection should include monitoring of the observation well to confirm that the trench is draining within the specified time. Trenches with filter fabric should be inspected for sediment deposits by removing a small section of the top layer. If inspection indicates that the trench is partially or completely clogged, it should be restored to its design condition.

When vegetated buffer strips are used, they should be inspected for erosion or other damage after each major storm event. The vegetated buffer strip should have healthy grass that is routinely mowed. Trash, grass clippings and other debris should be removed from the trench perimeter. Trees and other large vegetation adjacent to the trench should also be removed to prevent damage to the trench.

COSTS

Construction costs include clearing, excavation, placement of the filter fabric and stone, installation of the monitoring well, and establishment of a vegetated buffer strip. Additional costs include planning, geotechnical evaluation, engineering and permitting. The Southeastern Wisconsin Regional Planning Commission (SEWRPC, 1991) has developed cost curves and tables for infiltration trenches based on 1989 dollars. The 1993 construction cost for a relatively large infiltration trench (i.e., 6 feet deep and 4 feet wide with a 2,400 cubic foot volume) ranges from $8,000 to $19,000. A smaller infiltration trench (i.e., 3 feet deep and 4 feet wide with a 1,200 cubic foot volume) is estimated to cost from $3,000 to $8,500 (1993).

Maintenance costs include buffer strip maintenance and trench inspection and rehabilitation. SEWRPC (1991) has also developed maintenance costs for infiltration trenches. Based on the above examples, annual operation and maintenance costs would average $700 for the large trench and $325 for the small trench. Typically, annual maintenance costs are approximately 5 to 10 percent of the capital cost (Schueler, 1987). Trench rehabilitation, may be required every 5 to 15 years. Cost for rehabilitation will vary depending on site conditions and the degree of clogging. Estimated rehabilitation cost run from 15 to 20 percent of the original capital cost (SEWRPC, 1991).

ENVIRONMENTAL IMPACTS

Infiltration trenches provide efficient removal of suspended solids, particulate pollutants, coliform bacteria, organics and some soluble forms of metals and nutrients from storm water runoff. Infiltration trenches also reduce the volume of runoff by providing a storage reservoir. The captured runoff infiltrates the surrounding soils and increases groundwater recharge and base-flow in nearby streams.

Negative impacts include the potential for groundwater contamination. Fortunately, most pollutants have a low potential to contaminate groundwater (Schueler, 1987). However, an EPA study (USEPA, 1991) found that chloride and nitrate, which are very soluble pollutants, can migrate from infiltration trenches into groundwater. In the future, federal or state agencies may require a groundwater injection permit for infiltration trench sites (Schueler, 1992).

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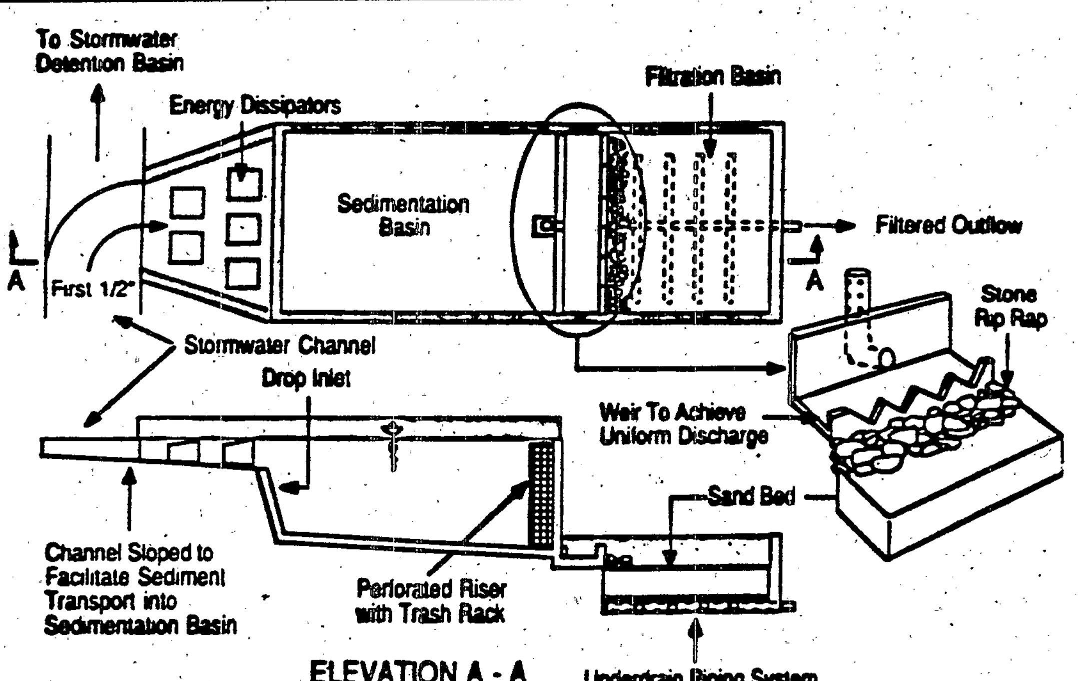
This fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC, 20460

STORM WATER BMP: SAND FILTERS

DESCRIPTION

Sand filters are most often designed for storm water quality control and generally provide limited storm water quantity management. A typical sand filter system consists of at least two chambers or basins with one designed for sedimentation and one for filtration. The first chamber, the sedimentation chamber, removes floatables and heavy sediments. The second chamber, the filtration chamber, removes additional pollutants by filtering the runoff through a sand bed. The treated filtrate normally is discharged through an underdrain system to a storm drainage system or directly to surface waters. Sand filters can achieve high removal efficiencies for sediment, biochemical oxygen demand (BOD) and fecal coliform bacteria. However, total metals removal is moderate and nutrient removal is often low.

There are three main sand filter designs currently in common use: the Austin sand filtration system (Figure 1a), the Washington, D.C. sand filter (Figure 1b) and the Delaware sand filter (Figure 1c). The primary differences in these designs are location (i.e., underground or surface and on-line or off-line), drainage area served, filter surface areas, land requirements, and quantity of runoff treated.



SOURCE: Reference 2

FIGURE 1a: TYPICAL AUSTIN SAND FILTER DESIGN

COMMON MODIFICATIONS

Modifications that may improve sand filter design and performance are being tested. One modification is the addition of a peat layer in the filtration chamber. The properties and characteristics of the peat may increase the microbial growth within the sand filter and improve pollutant (e.g., metals and nutrients) removal rates. Another design variation, which is included in the Washington, D.C. sand filter design, includes an underdrain that is extended above the sand filter layer. This allows for backwashing of the filter when it becomes clogged.

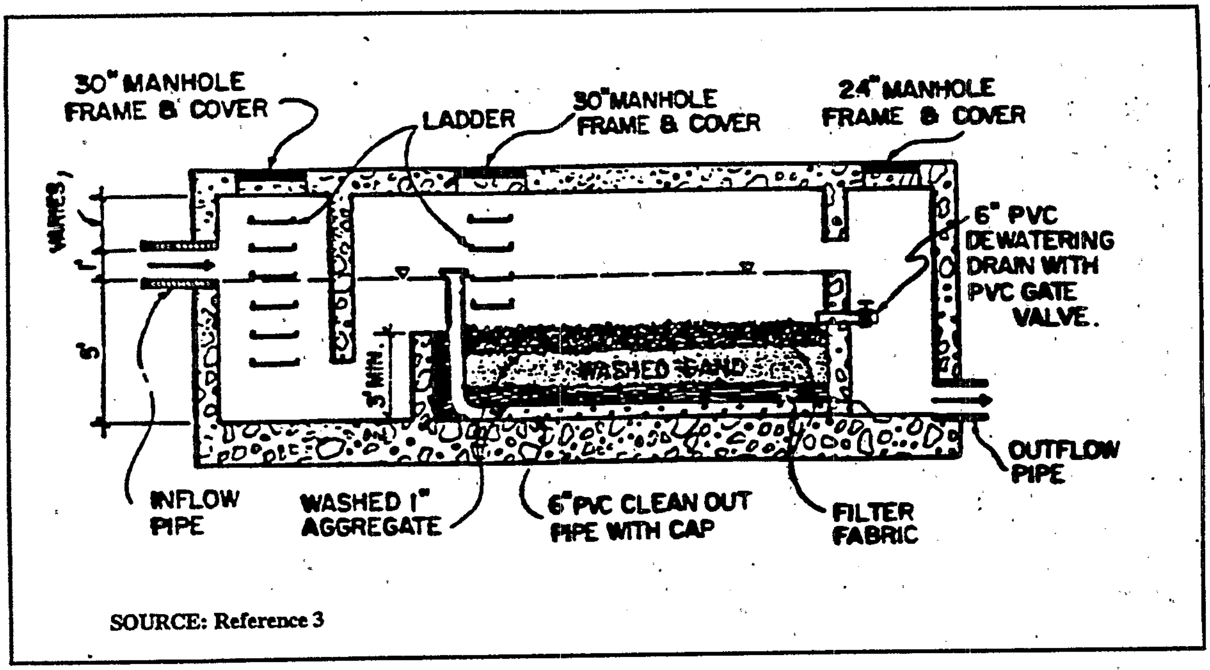


FIGURE 1b: TYPICAL WASHINGTON, DC SAND FILTER DESIGN

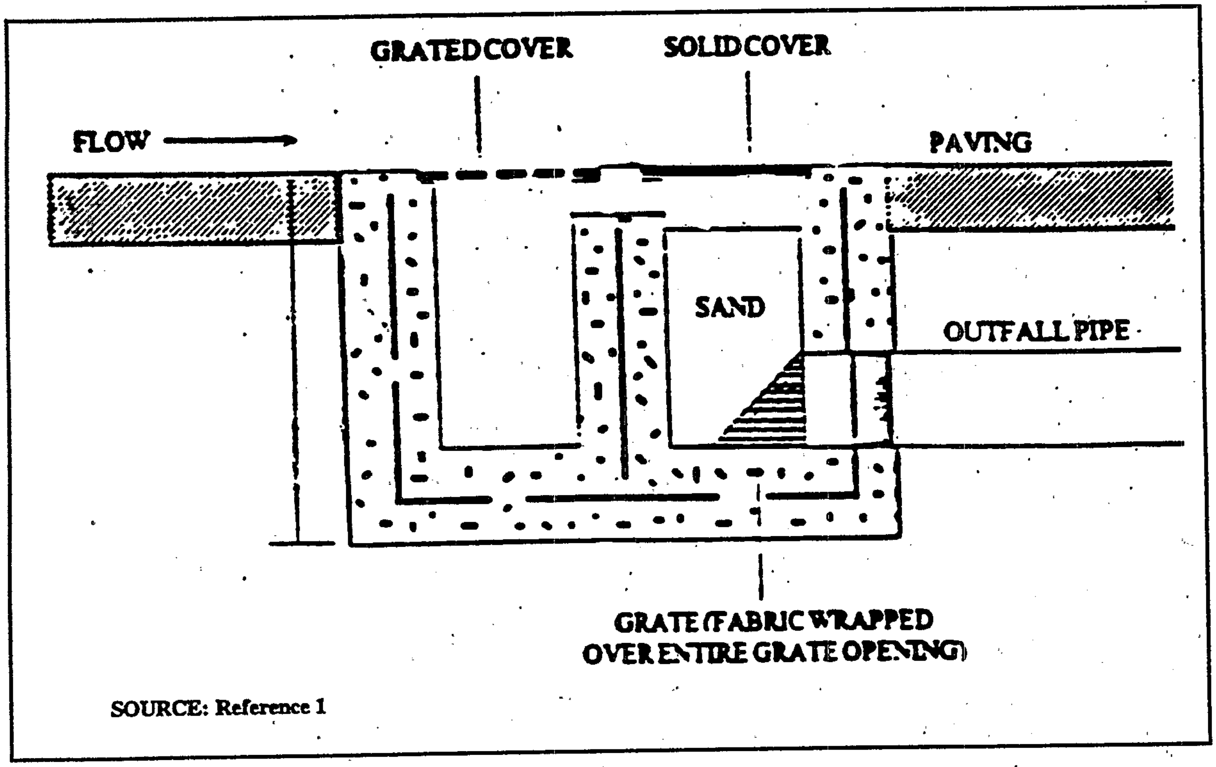


FIGURE 1c: TYPICAL DELAWARE SAND FILTER DESIGN

CURRENT STATUS

Sand filters are currently in use in the State of Delaware; and the Cities of Austin, Texas; Alexandria, Virginia; and Washington, D.C. Studies on the pollutant removal efficiencies are currently being performed for the Washington, D.C. and the Austin sand filters. However, additional evaluations need to be conducted in other locations and on alternative designs and media.

APPLICATIONS

In general, sand filters are preferred over infiltration practices, such as infiltration trenches, when groundwater contamination is of concern due to high ground water tables or in areas where underlying soils are unsuitable. In most cases, sand filters can be constructed with impermeable basin or chamber bottoms to collect, treat, and discharge runoff to a storm drainage system or directly to surface water without the contaminated runoff coming into contact with the groundwater.

The selection of the type of sand filter depends largely on the drainage area characteristics. For example, the Washington, D.C. and Delaware sand filter systems are well suited for highly impervious areas where land availability for structural controls is limited. Both the Washington, D.C. and Delaware sand filter designs are intended for underground installation. These sand filters are often used to treat runoff from parking lots, driveways, loading docks, service stations, garages, airport runways/taxiways, and storage yards. The Austin sand filtration system is more suited for larger drainage areas with both impervious and pervious surfaces. This system is located at grade and is often used at transportation facilities, large parking areas and commercial developments.

All three types of sand filters can generally be used as alternatives for water quality inlets, which are more frequently used to treat oil and grease contaminated runoff from drainage areas with heavy vehicle usage. In climatic zones where evaporation exceeds rainfall, the Austin sand filtration systems can also be used as an alternative to wet ponds for treatment of contaminated storm water runoff. In high evaporation zones, wet ponds will not likely be able to maintain the required permanent pool unless there is adequate baseflow from the groundwater.

LIMITATIONS

The size and characteristics of the drainage area as well as the pollutant loading will greatly influence the effectiveness of the sand filter system. In some cases other best management practices (BMPs), such as wet ponds, may be less costly for sites with large drainage areas and should also be considered if removal of nutrients and metals is required. Drainage areas with heavy sediment loads may result in frequent clogging of the filter. The lack of maintenance to the clogged filters will limit the performance. Certain climatic conditions may also limit the performance of the filters. For example, it is not known how well sand filters will operate in colder climates where sustained freezing conditions are encountered.

PERFORMANCE

Particulates are removed by both sedimentation in the sedimentation chamber and by filtration in the filtration chamber. The City of Austin has estimated pollutant removal efficiencies (Austin, 1988) based on preliminary findings of the City's storm water monitoring program. The estimates shown in Table 1 below, are average values for various sand filters serving several different size drainage areas.

As shown in Table 1, no removal of nitrate was observed in the preliminary findings. The removal of other dissolved pollutants was not monitored. Additional monitoring is currently being performed by the City of Austin to supplement the preliminary estimates.

LONGEVITY

There have been a number of concerns raised about the long term effectiveness of sand filter systems. Proper design and maintenance are critical factors in maintaining the useful life of any filter system. The life of the filter media may be increased by a number of methods including: stabilizing the drainage area so that sediments loadings in the runoff are minimized; placing a sedimentation chamber that removes sediments prior to the filtration chamber; providing adequate detention times for sedimentation and filtration to occur; and frequently inspecting and maintaining the sand filter to ensure proper operation. In some cases, replacement of the filter media may be required every 3 to 5 years. The useful life of the media will depend on the pollutant loading to the filter and the design and maintenance of the system.

TABLE 1: TYPICAL POLLUTANT REMOVAL EFFICIENCY

Pollutant	Typical Percent Removal
Fecal Coliform	76
Biochemical Oxygen Demand (BOD)	70
Total Suspended Solids (TSS)	70
Total Organic Carbon (TOC)	48
Total Nitrogen (TN)	21
Total Kjeldahl Nitrogen (TKN)	46
Nitrate as Nitrogen (NO_3-N)	0
Total Phosphorus (TP)	33
Iron (Fe)	45
Lead (Pb)	45
Zinc (Zn)	45

SOURCE: Reference 4

DESIGN CRITERIA

Typically the Austin sand filter system is designed to handle runoff from drainage areas up to 50 acres. The collected runoff is first diverted to the sedimentation basin, where heavy sediments and floatables are removed. There are two designs for the sedimentation basin: the full sedimentation system, as shown in Figure 1a, and a partial sedimentation system, where only the initial flow is diverted. Both systems are located off-line and are designed to collect and treat the first 0.5 inch of runoff. The partial system has the capacity to hold only a portion (at least 20%) of the first flush volume in the sedimentation basin, whereas the full system captures and holds the entire flow volume. Equations that are used to determine the sedimentation basin surface areas (A_s) in acres are shown in Table 2 below.

TABLE 2: SURFACE AREA EQUATION FOR THE AUSTIN SAND FILTER SYSTEM

Partial Sedimentation	Full Sedimentation
$A_s = (A_D)(H)/(1/D_s - 1/10)$	$A_s = (A_D)(H)/10$
$A_f = (A_D)(H)/10$	$A_f = (A_D)(H)/18$

Note:
D_s (feet) = depth of the sedimentation basin;
H (feet) = depth of rainfall, 0.042 ft (0.5 inches); and
A_D (acres) = impervious and pervious areas that provide contributing drainage.

SOURCE: Reference 4

Flow is conveyed from the sedimentation basin either through a perforated riser, gabion wall, or berm to the filtration basin. The filtration basin consists of an 18-inch layer of sand 0.02 to 0.04 inch in diameter that may be underlain with a gravel layer. Equations that are used to determine the filtration basin surface areas (A_f) in acres are also shown in Table 2. The filtrate is discharged from the filtration basin through underdrain piping 4 to 6 inches in diameter with 3/8-inch perforations. Filter fabric is placed around the underdrain piping to prevent sand and other particulates from being discharged.

Typically the Washington, D.C. sand filter system is designed to handle runoff from completely impervious drainage areas of 1 acre or less. The system, as shown in Figure 1b, consists of three chambers: a sedimentation chamber, a filtration chamber, and a discharge chamber. The reinforced concrete chambers are located underground. The sand filter system is designed to accept the first 0.5 inch of runoff. Coarse sediments and floatables are removed from the runoff within the sedimentation chamber. Runoff is discharged from the sedimentation chamber through a submerged weir, where it then enters the filtration chamber. The filtration chamber consists of a combination of sand and grave layers totaling 3 feet in depth with an underdrain system wrapped in filter fabric. The underdrain system collects the filtered water and discharges it to the third chamber, where the water is collected and discharged to a storm water channel or sewer system. An overflow weir is located between the second and third chambers to bypass excess flow. The Washington, D.C. sand filter is often constructed on-line, but can be constructed off-line. When the system is off-line the overflow between the second and third chambers is not included.

The Delaware sand filter, as shown in Figure 1c, is similar to the Washington, D.C. sand filter; both utilizing underground concrete vaults. However, the Delaware sand filter has two chambers: a sedimentation chamber and a filtration chamber. A 1-inch design storm was selected for the sizing of the sedimentation basin because it is representative of most frequent storm events. In Delaware, 92% of all storms are less than 1 inch in depth. Runoff enters the sedimentation chamber through a grated cover and then overflows into the filtration chamber, which contains a sand layer 18 inches in depth. Gravel is not normally used in the filtration chamber, although the filter can be modified to include gravel. Typical systems are designed to handle runoff from drainage areas of 5 acres or less. A major advantage of the Delaware sand filter is its shallow structure depth of only 30 inches, thereby reducing excavation requirements.

MAINTENANCE

All filter system designs must provide adequate access to the filter to perform the required inspection and maintenance. The sand filters should be inspected after all storm events to verify that they are working as designed. Since the D.C. and Austin sand filter systems can be relatively deep, they may be designated as confined spaces, therefore, require compliance with confined space entry safety procedures.

Typically, sand filters begin to experience clogging problems within 3 to 5 years (NVPDC, 1992). Accumulated trash, paper and debris should be removed from the sand filters every 6 months or as necessary to keep the filter clean. A record should be kept of the dewatering times for all sand filters to determine if maintenance is necessary. Corrective maintenance of the filtration chamber includes removal and replacement of the top layers of sand, gravel and/or filter fabric that have become clogged. The removed media may usually be disposed of in a landfill. The City of Austin has tests their waste media before disposal. Results thus far indicate that the waste media is not toxic and can be safely landfilled (Schueler, 1992). Sand filter systems may also require the periodic removal of vegetative growth.

COSTS

The construction cost for an Austin sand filtration system is approximately $17,750 (1993 dollars) for a 1-acre drainage area. The cost per acre decreases with increasing drainage area. For example the cost for a 15-acre site is approximately $3,300 (1993 dollars) per acre for a total of $49,500 (Austin, 1990b). The cost for precast Washington, D.C. sand filters with drainage areas of less than 1 acre ranges between $6,300 and $10,500. This is considerably less than the cost for the same size cast-in-place system of approximately $26,400 (D.C., 1992). Costs for the Delaware sand filter are similar to that of the D.C. system, except the excavation costs are generally lower, because of the filters shallower depth.

Annual costs for maintaining sand filter systems averages about 5 percent of the initial construction cost (Schueler, 1992). Media replacement is performed as needed. Currently the sand is being replaced in the D.C. filter systems about every 2 years. The cost to replace the gravel layer, filter fabric and top portion of the sand for D.C. sand filters is approximately $1,600 (D.C. 1992). The City hopes that improved maintenance procedures will extend the life of the filter media and reduce the overall maintenance costs.

ENVIRONMENTAL IMPACTS

The three types of sand filters achieve high removal efficiencies for sediment, BOD and fecal coliform bacteria and generally require less land than other BMPs, such as ponds or wetlands. Sand filters constructed with impermeable basin liners limit the potential for groundwater contamination. Sand filters generally do not provide storm water quantity control and, therefore, do not prevent downstream stream bank and channel erosion. Sand filters may also be of limited value in some applications because of their traditionally low nutrient removal and metals removal capabilities. Waste media from the filters does not appear to be toxic and is environmentally safe for landfill disposal.

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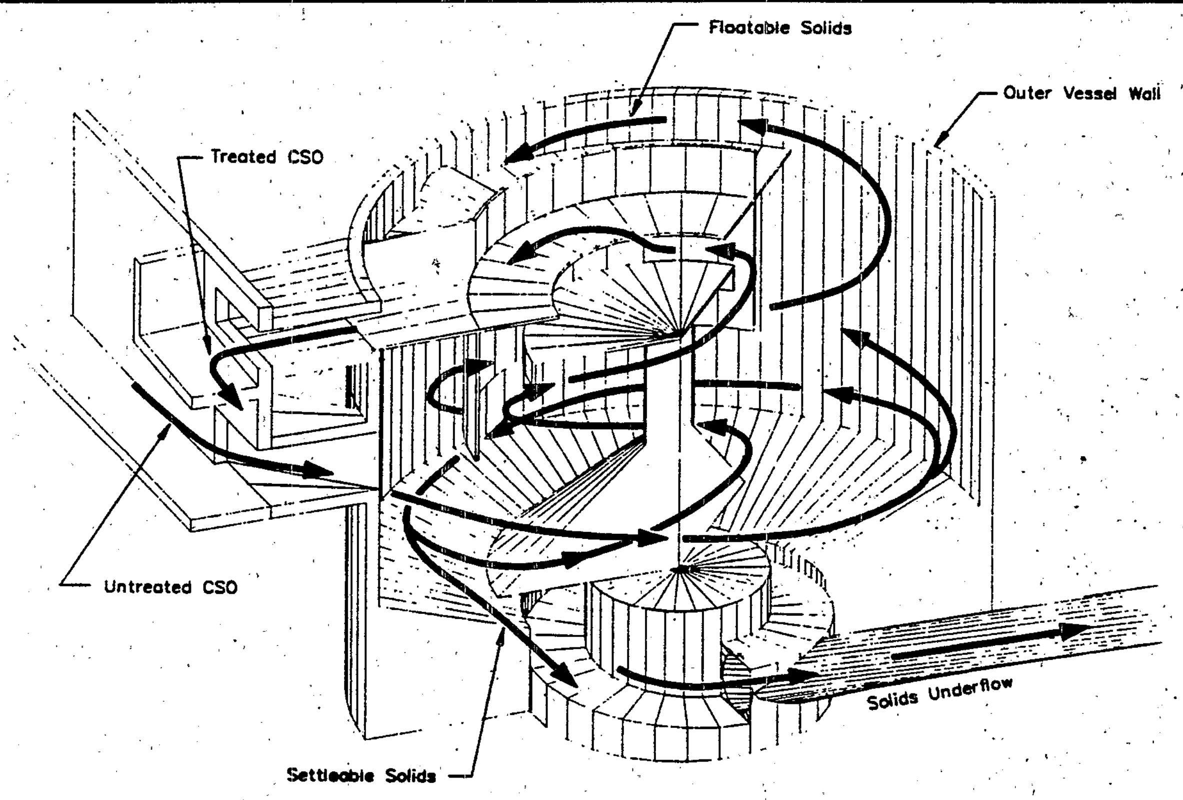
STORM WATER BMP: VORTEX SOLIDS SEPARATOR

DESCRIPTION

A vortex solids separator is a wastewater treatment technology with no moving parts which uses velocities imparted from vortex swirling to assist the settling and removal of concentrated solids. During a storm event, flow enters the cylindrical unit tangentially and induces a swirling vortex which concentrates solids in the underflow and reduces their concentration in the clarified liquid. A general view of the vortex solid separator and liquid flow paths is shown in Figure 1 below.



SOURCE: Reference 19

FIGURE 1: GENERAL VIEW OF THE VORTEX SOLID SEPARATOR

Vortex units are most often applied to combined sewer overflow (CSOs), but can also be used to treat storm water runoff. In CSO treatment applications, the concentrated solids are removed from the bottom of the unit and conveyed via the sanitary sewer to a wastewater treatment plant (WWTP). In separate storm water applications, the concentrated underflow would likely go to a holding tank or pond. Effluent exits the top of the unit and is discharged to the receiving water. Vortex units may be used on-line or off-line, and in combination with other Best Management Practices (BMPs) such as storage tanks or detention ponds.

CURRENT STATUS

This fact sheet contains general information only, and should not be used as the basis for designing a vortex solids separators for storm water applications . While the basic vortex separator technologies used for CSO applications are well established, actual operating experience for storm water applications is limited. The three types of vortex solids separators currently being actively marketed in the United States are listed below. While all three types use the same basic principal, this fact sheet will discuss some of the differences in design and performance of the different units. The technology for storm water applications is evolving rapidly. The equipment manufacturers and the municipal operators should be contacted for the current state of the art information.

- The EPA Swirl Concentrator.
- The Fluidsep.
- The Storm King.

The design specifications for the EPA Swirl Concentrator were developed by the U.S. Environmental Protection Agency (EPA) in the early 1970s. Currently, there are 20 full-scale EPA Swirl Concentrator units in the U.S. and four in Japan (EPA, 1977). All of these units were designed for CSO treatment. However, the EPA Swirl Concentrator design was extensively tested during a study for separated storm water treatment in West Roxbury, Massachusetts in the early 1980s (EPA, 1982, 1984).

Fluidsep is a patented design that is licensed by a German firm, but is available in the U.S. There are 13 full-scale Fluidsep units operating in the U.S. and Europe, with additional units planned for construction. Fluidsep has been consistently used for CSO applications and has not been tested on separated storm-sewer systems.

Storm King, a patented unit, is available in the U.S. from H.I.L. Technology, Inc. There are no full-scale Storm King units in operation in the U.S. at this time. However, there are more than 100 Storm King treatment units in operation in Europe and Canada, almost exclusively on CSOs. Full-scale Storm King units have been selected by the City of Columbus to treat CSOs. Storm water treatment by the Storm King has been limited to a pilot study in Bradenton, Florida and a full-scale unit in Surrey Heath, England.

APPLICABILITY

Vortex separators are most effective where the separation of gritty materials, heavy particulates or floatables from wet-weather runoff is required. The technology is particularly well suited to locations where there is limited land availability which may preclude the use of other BMPs such as settling basins or detention ponds. Vortex separators can also be applied as satellite units to treat smaller subareas of the collection system, minimizing the high cost of conveyance systems needed for centralized treatment facilities. Units can be designed to remove solids and capture floatables. However, solids with poor settleability are not effectively removed in vortex solids separators.

LIMITATIONS

The use of vortex solids separators as a wet-weather treatment option may be limited by the poor net solids removal (10-34 percent). In some cases this level of solids removal may not meet the treatment objectives for a potential location. There is even less information on the ability of vortex solids separators to remove pollutants other than solids. Pollutants such as nutrients and metals that adhere to fine particulates or are dissolved will not be significantly removed by the vortex separator.

Site constraints, including the availability of suitable land, appropriate soil depth and stability to structurally support the unit, may also limit the applicability of the vortex separator. The slope of the site or collection system may dictate the use of an underground unit, which can result in extensive excavation. For above-ground units, pumping may be required. Maintaining and operating these pumping facilities will increase the capital costs as well as the energy, operations and maintenance cost of the vortex solids separator.

DESIGN

Regardless of the type of vortex separator selected, the type and quantity of pollutants to be removed must first be determined. The settleability characteristics and the quantity of flow to be treated will then established for proper design to achieve the desired treatment level. The settling characteristics of particulates anticipated in the influent are the basis of the design of all unit types.

The performance of each unit is based on the vortex separation mechanism. Each unit type has its own design criteria to achieve solids/liquids separation. The design of the EPA Swirl Concentrator is based on settleability studies developed in the 1970s. This information is available in the public domain from EPA design manuals (USEPA, 1977). Design of the Storm King units is based on pilot-scale treatability studies. Pilot-scale testing is conducted at each installation to select the appropriate full-scale unit design that best suits the intended application. The Fluidsep design is based on modeling of particulate settleability determined during site-specific studies, including flow gauging and rainfall measurements.

PERFORMANCE

Vortex separators designed primarily for removing grittier material, may have difficulty removing the less settleable solids often found in storm water runoff. For CSO applications, average total mass solids removals varied between 38%, at the EPA Swirl Concentrator facility in Washington, D.C., to 61%, at the Storm King pilot-study facility in Columbus, Georgia. For storm water runoff applications, average total mass solids removal was observed to be approximately 26%, at the pilot-scale Swirl Concentrator demonstration test in West Roxbury, Massachusetts. Average performance characteristics for the three different types of separators in shown in Table 1 below. This data is for CSO applications only.

Solids are removed in the underflow by flow splitting even if there is no concentration of particulates in the underflow from the vortex unit. The removal of solids in the underflow may account for a large portion of the total mass solids removed in the unit. To discount the solids removed by the underflow without concentration by the unit, net solids removals were determined. Net solids removals exclude from the total solids removal, the solids removed by the underflow by flow-splitting. Net solids removals for CSO applications, as shown in Table 1, were observed to a low of 7% for Tengen, Germany and a high of 34%, for Columbus, Georgia. The average net mass solids removal for separate storm water applications was observed to be a high of 17% for the EPA Swirl Concentrator tested at West Roxbury, Massachusetts and a low of 12% for the Storm King unit tested at Bradenton, Florida. However, the data for storm water runoff applications is not considered sufficient to allow for the evaluation of performance between unit designs and is not included in Table 1.

MAINTENANCE

Vortex separators do not have any moving parts, and are therefore not maintenance intensive. However, wash downs are required following every CSO event to prevent odors. To accomplish this, some

TABLE 1: AVERAGE VORTEX PERFORMANCE CHARACTERISTICS FOR CSO APPLICATIONS

Unit Type	Location	Effluent Hydraulic Flow (MGD)	Solids Reduction	Solids Removal	Total Net Treatment Removal	Factor
Swirl	Washington, DC	10	24	38	12	1.7
Fluidsep	Tengen, Germany	11	47	54	7	1.2
Storm King	James Bridge, UK	7.5	39	53	14	1.7
Storm King	Columbus, GA	4.3	23	61	34	2.6

SOURCE: References 10, 11, 20, and 21

units have been designed to be self-cleansing. This may not be necessary for storm water treatment applications. Pretreatment

BMPs such as bar screens or street sweeping can be used to decrease the quantity of wastes reaching the vortex separators, but it is not required. Maintenance would be required for pretreatment and pumping equipment.

COSTS

The capital cost for vortex solids separator treatment facilities are dependant on site-specific characteristics. Commonly, vortex solids separators are used with other treatment technologies such as automatic bar screens, and disinfection. The capital cost for vortex solids separator treatment facilities in the U.S. varies between $3,000 and $5,250 per acre of drainage basin (1993 dollars). Typically the capital cost for installed vortex solids separator units without pretreatment is approximately $4,900 per million gallons of flow treated (1993 dollars).

Total costs of vortex units often include predesign costs, capital costs and operation and maintenance (O&M) costs. Foe example, predesign study costs for the Storm King are typically $20,000 (1993 dollars). Predesign costs for the Fluidsep, range between $25,000 and $100,000 (1993 dollars). There are no predesign study costs associated with the EPA Swirl Concentrator, because published settleability curves are used for the basis of design.

Vortex solids separator units do not generally require significant energy expenditures unless pumping is required. Operating expenses primarily include labor for wash down or energy costs for automatic wash down or bar screens. However some installations such as the Storm King unit in Surry Heath, England, do not have a sanitary or foul sewer line for disposing of collected solids. These facilities must collect its residuals in a collection zone or holding tank. The frequency for pumping out the collected residuals will be dependent on the amount of material collected per storm, the number of storm events and the size of the holding zone or tank. The Surry Heath facility is estimating the holding zone will require pump out every 2-3 years. The cost for periodic emptying and disposal of the collected residuals is estimated to be between $300-450 per cleaning (1993 dollars).

ENVIRONMENTAL IMPACTS

Improvements can often be observer in water quality or in the health of the ecosystem. For example, the Washington, D.C. CSO Abatement Program, which includes EPA Swirl Concentrators and upstream storage, has resulted in decreased oxygen demands in the receiving water. Fish have returned to the once oxygen-depleted water. Much of the improved receiving water quality is attributable due to a combination of the upstream storage, and the bar screens, disinfection, and operation of the vortex units.

For CSO applications the vortex solid separators must be washed down after each storm events to prevent objectionable odors. Odor control for some storm water applications and for residual storage facilities may also be required. Collected residuals from storm water applications have not evaluated. However, collected residuals should be evaluated for toxicity and metals content before disposal.

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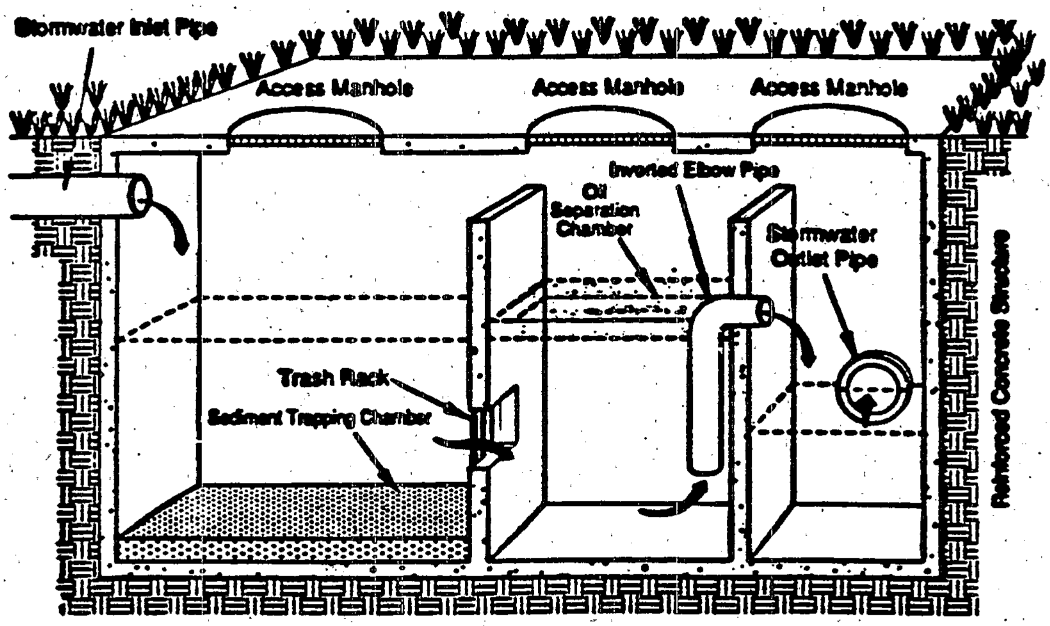
STORM WATER BMP: WATER QUALITY INLETS

MTB
Office of Wastewater Management
MUNICIPAL TECHNOLOGY BRANCH

DESCRIPTION

Water quality inlets (WQIs) consist of a series of chambers that allow sedimentation of coarse materials, screening of larger or floating debris, and separation of free oil (as opposed to emulsified or dissolved oil) from storm water. They capture only the first portion of runoff for treatment and are generally used for pretreatment before discharging to other best management practices (BMPs). A typical WQI, as shown in Figure 1 below, consists of a sediment chamber, an oil separation chamber and a discharge chamber. WQIs are also commonly called oil/grit separators or oil/water separators. WQIs can be purchased as a pre-manufactured unit or can be constructed on site.



SOURCE: Reference 3

FIGURE 1: PROFILE OF A TYPICAL WATER QUALITY INLET

COMMON MODIFICATIONS

The design of WQIs can be modified to improve their performance. Possible modifications include (1) an additional orifice and chamber that replace the inverted pipe elbow, (2) the extension of the second chamber wall up to the top of the structure, or (3) the addition of a diffusion device at the inlet. The diffusion device is intended to dissipate the velocity head and turbulence and distribute the flow more evenly over the entire cross-sectional area (API, 1990). Suppliers of pre-manufactured units (i.e., Highland Tank & Mfg., Jay R. Smith Mfg., etc.) can also provide modifications of the typical design for special conditions.

CURRENT STATUS

WQIs are widely used in the U.S.; however, recent studies indicate that the lack of regular maintenance adversely affect their performance. There is also some concern that, because the collected residuals contain hydrocarbon by-products, the residuals may be considered too toxic for conventional landfill disposal. Maintenance requirements and residual disposal, should be carefully evaluated in selecting a WQI. Possible alternatives to the WQI include sand filters, oil absorbent materials, and other innovative BMPs (i.e., Stormceptor System).

APPLICATIONS

WQIs are often used where land requirements and cost prohibit the use of larger BMP devices, such as ponds or wetlands. WQIs are also used to treat runoff prior to discharge to other BMPs. WQIs can be adapted to all regions of the country (Schueler, 1992), and are typically located in small, highly impervious areas, such as gas stations, loading areas or parking areas. Sites with high automotive related uses can be expected to have higher hydrocarbon concentrations than other land uses (MWCOG, 1993). Increased maintenance and residual disposal, due to these higher hydrocarbon concentrations from these areas, must be carefully evaluated before selecting a WQI for these applications.

LIMITATIONS

Two major constraints limit the effectiveness of WQIs. Theses constraints are (1) the size of the drainage area and (2) the activity within the drainage area. WQIs are generally recommended for drainage areas of 1 acre or less (Berg, 1991, NVPDC, 1992). Construction costs often become prohibitive for larger drainage areas. High sediment loads interfere with the ability of the WQI to effectively separate oil and grease from the runoff. Therefore, WQIs should not accept runoff from disturbed areas unless the runoff has been pretreated to reduce the sediment loads to acceptable levels.

WQIs are also limited by maintenance requirements and pollutant removal capabilities. Maintenance of underground WQIs can be easily neglected because the WQI is often "out of sight and out of mind." Regular maintenance is essential to ensuring effective pollutant removal. Lack of maintenance will often result in resuspension of settled pollutants. WQIs are most effective in removing heavy sediments and floating oil and grease. WQIs have demonstrated limited ability to separate dissolved or emulsified oil from runoff. WQIs are also not very effective at removing pollutants such as nutrients or metals, except where the metals are directly related to sediment removal.

PERFORMANCE

More than 95 percent of all WQIs operate as designed during their first 5 years. Very few structural or clogging problems or problems with the separation of the pollutants and water are experienced during that period. However, WQIs have a very poor record of pollutant removal due to a lack of regular clean-outs and the resuspension of the sediments (Schueler, 1992). The efficiency of oil and water separation in a WQI is inversely proportional to the ratio of the discharge rate to the unit's surface area (API, 1990). Due to the small capacity of the WQI, the discharge rate is typically very high and the detention time is very short, which can result in minimal pollutant settling. The average detention time in a WQI is less than 0.5 hour (MWCOG, 1993).

The WQI achieves slight, if any, removal of nutrients, metals and organic pollutants other than free petroleum products (Schueler, 1992). Grit and sediments are partially removed by gravity settling within the first two chambers. A WQI with a detention time of 1 hour may expect to have 20 to 40 percent removal of sediments.

The Metropolitan Washington Council of Governments (MWCOG) performed a long-term study to determine WQI performance and effectiveness. Monitoring of more than 100 WQIs indicated that less than 2 inches of sediments (mostly coarse-grained grit and organic matter) were trapped in the WQIs. Hydrocarbon and total organic carbon (TOC) concentrations of the sediments averaged 8,150 and 53,900 mg/kg, respectively. The mean hydrocarbon concentration in the WQI water column was 10 mg/L. The study also indicated that sediment accumulation did not increase over time, suggesting that the sediments become re-suspended during storm events (MWCOG, 1993). Although the design of the WQI effectively separates oil and grease from water, re-suspension of the settled matter appears to limit removal efficiencies. Actual removal occurs when the residuals are removed from the WQI (Schueler 1992).

DESIGN CRITERIA

Prior to WQI design, the site should be evaluated to determine if another BMP would be more cost-effective in removing the pollutants of concern. WQIs should be used where no other BMP is feasible. The site should be near a storm drain network so that flow can be easily diverted to the WQI for treatment (NVPDC, 1992). Construction activities within the drainage area should be completed and the drainage area should be revegetated so that the sediment loading to the WQI is minimized. Upstream sediment control measures should be installed to decrease the sediment loading.

WQIs are most effective for small drainage areas. Drainage areas of 1 acre or less are often recommended. WQIs are typically used in an off-line configuration (i.e., portions of runoff are diverted to WQI), but they can be used as an on-line unit (i.e., receive all runoff). Generally off-line units are designed to handle the first 0.5 inches of runoff from the drainage ares. Upstream isolation/diversion structures can be used to divert the water to the off-line structure (Schueler, 1992). On-line units receive higher flows that will likely cause increased turbulence and resuspension of settled material; thereby reducing WQI performance.

Chamber Design

Structural loadings should be considered in the WQI design (Berg, 1991). WQIs are available in pre-manufactured units or can be cast-in-place. Reinforced concrete should be used to construct below-grade WQIs. The WQIs should be water tight to prevent possible ground water contamination. The first and second chambers are generally connected by an opening covered by a trash rack or by a PVC or other suitable material pipe (Berg, 1991). If a pipe is used it should also be covered by a trash rack or screen. The opening or pipe between the first and second chambers should be designed to pass the design storm with out surcharging the first chamber (Berg, 1991). The design storm will vary depending on geographical location and is generally definite by local regulations.

When the combined length of the first two chambers exceeds 12 feet, the chambers are typically designed with the length of the first and second chamber being 2/3 and 1/3 of the combined length respectively. Each of the chambers should have a separate manhole to provide access for cleaning and inspection.

The State of Maryland design standards indicate that the combined volume of the first and second chambers should be determined based on 40 cubic feet per 0.10 acre draining to the WQI. In Maryland, this is equivalent to capturing the first 0.133 inch of runoff from the contributing drainage area. The combined volume includes the volume of the first and second chamber up to the top of the interior walls and the volume of the permanent pool (Berg, 1991).

Permanent pools within the chambers help prevent the possibility of sediment resuspension. The first and second chambers should have permanent pools with 4-foot depths. If possible, the third chamber should also contain a permanent pool (NVPDC, 1992).

In the standard WQI, an inverted elbow is installed between the second and third chamber. The elbow should extend a minimum of 3 feet into the second chamber's permanent pool in order to retain oil (NVPDC, 1992). The elbow should be capable of passing the design storm to prevent frequent discharge of accumulated oil. The size of the elbow or number of elbows can be adjusted to accommodate the design flow (Berg, 1991).

MAINTENANCE

WQIs should be inspected after every storm event to determine if maintenance is required. At a minimum each WQI should be cleaned at the beginning of each change in season (Berg, 1991). The required maintenance will be site-specific due to variations in sediment and hydrocarbon loading. Maintenance should include clean-out and disposal of the sediments and removal of trash and debris. The clean-out and disposal techniques should be environmentally acceptable and in accordance with local regulations. Since WQI residuals contain hydrocarbon by-products they may require disposal as a hazardous waste. Many WQI owners contract with waste haulers to collect and dispose of these residuals. Since WQIs can be relatively deep, they may be designated as confined spaces. Caution should be exercised to comply with confined space entry safety regulations in the event that entry into the WQI is required.

COSTS

The construction costs for WQIs will vary greatly depending on the size and depth required. The construction costs (in 1993 dollars) for cast-in-place WQIs range from $5,000 to $16,000, with the average WQI costing around $8,500 (Schueler, 1992). For the basic design and construction of WQIs, the pre-manufactured units are generally less expensive than those cast-in-place (Berg, 1991).

Maintenance costs will also vary greatly depending on the size of the drainage, the amount of the residuals collected, and the clean-out and disposal methods available (Schueler, 1992). The cost of residuals removal, analysis and disposal can be major maintenance expense, particularly if the residuals are toxic and are not suitable for disposal in a conventional landfill.

ENVIRONMENTAL IMPACTS

WQIs can effectively trap trash, debris, oil and grease, and other floatables that would otherwise be discharged to surface waters (Schueler, 1992). The 1993 MWCOG study found that pollutants in the WQI sediments were similar to those pollutants found in downstream receiving water sediments (the tidal Anacostia River). This information suggests that downstream sediment contamination is linked to contaminated runoff (MWCOG, 1993). A properly designed and maintained WQIs can be an effectively BMP for reducing hydrocarbon contamination in receiving water sediments.

WQIs generally provide limited hydraulic and residuals storage. Due to the limited storage, WQIs do not provide adequate storm water quantity control. The WQI residuals require frequent removal and may require disposal as a hazardous waste. The 1993 MWCOG study found that the residuals from WQIs typically contain many priority pollutants, including polyaromatic hydrocarbons, trace metals, pthalates, phenol, toluene, and possibly methylene chloride (MWCOG, 1993). During periods of high flow, the residuals may be resuspended and released from the WQI to surface waters.

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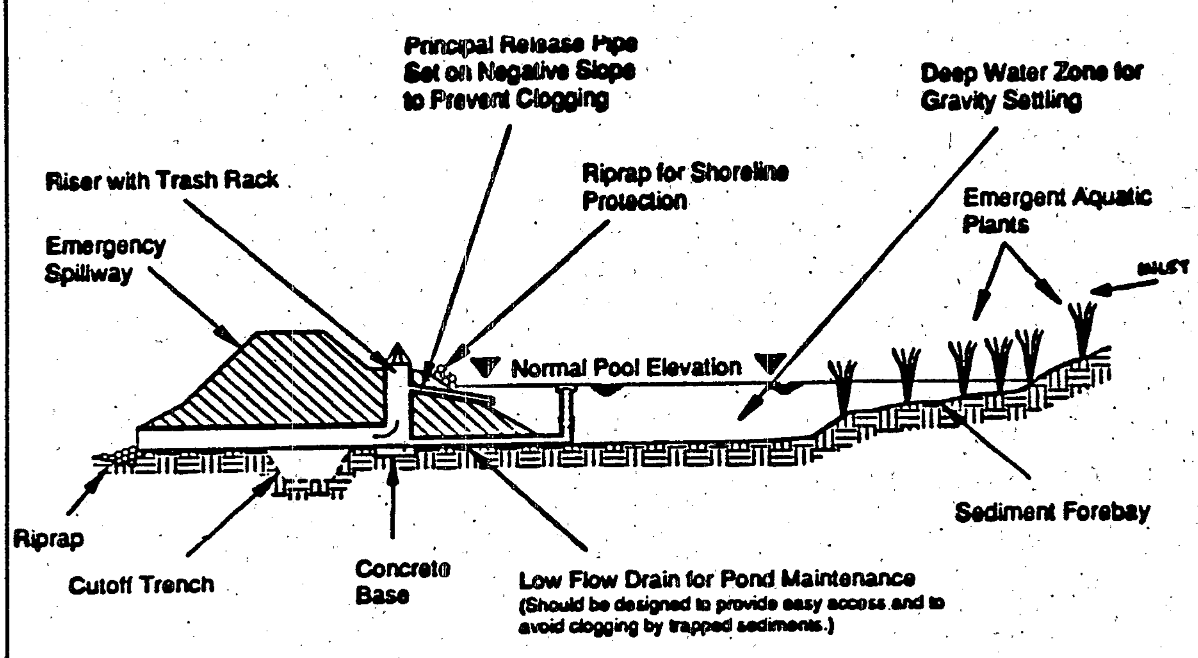
STORM WATER BMP: WET DETENTION PONDS

MTB
Office of Wastewater Management
MUNICIPAL TECHNOLOGY BRANCH

DESCRIPTION

Wet detention ponds provide both retention and treatment of contaminated storm water runoff. A typical wet detention pond is shown in Figure 1 below. A wet detention pond maintains a permanent pool of water where pollutant removal is achieved through physical, biological and chemical processes. Storm water runoff is detained in the pond until runoff from the next storm event mixes with and displaces some of the treated water before discharge to receiving waters. Discharge from the pond is controlled by a riser and an inverted release pipe.



SOURCE: Reference 2

FIGURE 1: TYPICAL LAYOUT OF A WET DETENTION POND

Wet detention ponds remove sediment, organic matter and metals by sedimentation and remove dissolved metals and nutrients through biological uptake. Effective pollutant removal can be achieved if the pond is properly designed and maintained (SEWPRC, 1991).

COMMON MODIFICATIONS

A typical wet pond may be enhanced with the addition of a sediment forebay, as shown in Figure 1, or by constructing shallow ledges along the edge of the permanent pool. Runoff passes through the sediment forebay where the heavier sediments drop out of suspension, while additional removal of lighter sediments occurs in the permanent pool. The shallow, peripheral ledges contain aquatic plants that trap pollutants as they enter the pond. Biological activity also increases due to the aquatic plants, and results in increased nutrient removal. Perimeter wetland areas can also be created that will aid in pollutant removal. The ledges also act as a safety precaution from accidental drowning and provide easy access for maintenance to the permanent pool.

Treatment within a pond can be enhanced through extending the detention time in the permanent pool. This allows for a more gradual release of collected runoff from a design storm over a specified time (Hartigan, 1988). This results in increased pollution removal as well as control of peak flows.

CURRENT STATUS

Wet detention ponds have been widely used throughout the U.S. for many years to treat of storm water runoff. Many of these ponds have been monitored to determine their performance. EPA Region V is currently performing a study on the effectiveness of 50 to 60 wet detention ponds. Other organizations, such as the Washington, D.C., Council of Governments (Wash COG) have also conducted extensive evaluations of wet detention pond performance (Schueler, 1992). Wet detention ponds provide the benefit of both storm water quantity and quality control. In general, a higher level of nutrient removal and better storm water quantity control can be achieved in wet detention ponds than can be achieved with other best management practices (BMPs), such as infiltration trenches or sand filters. However, proper maintenance is essential to maintaining these higher levels of treatment.

LIMITATIONS

Wet detention ponds must be able to maintain a permanent pool. Therefore, ponds should not be constructed in areas where there is insufficient precipitation or on soils that are highly permeable. In wetter regions, a small minimum drainage area may be adequate, where as, in more arid regions, a larger drainage areas may be required in order to ensure sufficient water to maintain the permanent pool. In some cases, soils that are highly permeable may be compacted or overlaid with clay blankets to make the bottom less permeable. Land constraints, such as small sites or highly developed areas, may also preclude the use of a pond. In addition, the local climate (i.e., temperature) may affect the biological uptake in the pond. With out proper maintenance, the performance of the pond will drop off sharply. Regular cleaning of the forebays is particularly important. Maintaining the permanent pool is also important in preventing the resuspension of trapped sediments. In most cases no specific limitations have been places on disposal of sediments removed from wet detention ponds. Studies to date indicate that pond sediments are likely to meet toxicity limits and can be safely landfilled (Schueler, 1992). Some states have allowed sediment disposal on-site, as long as the sediments are deposited away from the shoreline, preventing their reentry into the pond.

PERFORMANCE

The primary pollutant removal mechanism in a wet detention pond is sedimentation. Suspended pollutants, such as metals, nutrients, sediments, and organics, are partly removed by sedimentation. Other pollutant removal mechanisms include algal uptake, wetland plant uptake and bacterial decomposition (Schueler, 1992). Dissolved pollutant removal occurs as a result of biological and chemical processes (NVPDC, 1992).

The removal rates of conventional wet detention ponds (i.e., without the sediment forebay or peripheral ledges) are well documented and are shown in Table 1 below. The wide range in the removal rates is a result of varying hydraulic residence times (HRTs), which is further discussed in the Design Criteria section. Increased pollutant removal by biological uptake and sedimentation is correlated with increased HRTs. Proper design and maintenance also affect pond performance.

Studies have shown that more than 90 percent of the pollutant removal occurs during the quiescent conditions (i.e., the period between the rainfall events) (MD, 1986). However, some removal occurs during the dynamic period (i.e., when the runoff enters the pond).

TABLE 1: REMOVAL EFFICIENCIES FROM WET DETENTION PONDS

Parameter	Percent Removal	
	Schueler, 1992[1]	Hartigan, 1988[2]
Total Suspended Solid	50 - 90	80 - 90
Total Phosphorus	30 - 90	
Soluble Nutrients	40 - 80	50 - 70
Lead	70 - 80	
Zinc	40 - 50	
Biochemical Oxygen Demand or Chemical Oxygen Demand	20 - 40	

[1] hydraulic residence time varies
[2] hydraulic residence time of 2 weeks

SOURCE: Reference 1
SOURCE: Reference 2

DESIGN CRITERIA

Well designed and properly maintained ponds can function as designed for 20 years or more. Concrete risers and barrels have a longer life than corrugated metal pipe risers and barrels and are recommended for most permanent ponds (Schueler, 1992). The accumulation of sediments in the pond will reduce the storage capacity and cause a decline in performance. Therefore, the bottom sediments in the permanent pool should be removed every 2 to 5 years or as necessary. The design of the pond should allow easy access to the forebays for frequent sediment removal.

All local, state and federal permit requirements should be established prior to starting the pond design. Depending on the location of the pond, required permits and certifications may include wetland permits, water quality certifications, dam safety permits, sediment and erosion control plans, waterway permits, local grading permits, land use approvals, etc.(Schueler, 1992). Since many states and municipalities are still in the process of developing or modifying storm water permit requirements, the applicable requirements should be confirmed with the appropriate regulatory authorities.

Prior to designing the pond, a site should be selected that is able to support the pond environment. The cost effectiveness of locating a pond at that site should also be carefully evaluated. The site must have adequate base-flow from the groundwater or from the drainage area to maintain the permanent pool. Typically, underlying soils with permeability between 10^{-5} and 10^{-6} cm/sec will be adequate so that a permanent pool can be maintained. In addition, the pond should be located where the topography of the site allows for maximum storage at minimum construction costs (NVPDC, 1992). Land constraints to avoid include existing utilities (e.g., electric or gas) that would be costly to relocate and excavation of bedrock that would require expensive blasting operations.

The design of wet detention ponds should serve two functions: storm water quantity control and storm water quality control. Storm water quantity requirements are typically met by designing the pond to control post-development peak discharge rates to pre-development levels. Various routing models (i.e., Soil Conservation Service TR-20 or EPA SWMM) can be used to calculate the required storm water storage. Usually the pond is designed to control multiple design storms (e.g., 2- and/or 10-year storms) and safely pass the 100-year storm event. However, the design storm may vary depending on local conditions and requirements.

Storm water quality control is achieved in the permanent pool, which is designed by either the eutrophication method or the solids settling method (Hartigan, 1988). Several models are available for both methods. The solids settling method accounts for pollutant removal through sedimentation, whereas the eutrophication method accounts for dissolved nutrient removal that occurs as a result of biological processes. Equations for the Walker eutrophication model are shown in Table 2 below. The solids settling method indicate that two-thirds of the sediment, nutrients and trace metal loads are removed by sedimentation within 24 hours. Theses projections are supported by the results of the EPA's 1993 National Urban Runoff Program (NURP) studies. However, other studies indicate that a hydraulic residence time (HRT) of 2 weeks is required to achieve significant phosphorus removal (MD, 1986). This longer HRT is similar to the HRT determined by the eutrophication method. In some cases, the HRTs calculated by the eutrophication method are up to three times greater than HRTs calculated by the solids settling method. These longer HRTs appear to be due to the slower reaction rates associated with the biological removal of dissolved nutrients. This results in a permanent pool that is approximately three times larger than the permanent pool calculated by solids settling models (Hartigan, 1988). Other design methods, such as sizing the permanent pool to collect a specific volume of runoff from the drainage area, have been tried with varying degrees of success, and are not described in this fact sheet.

TABLE 2: WALKER EUTROPHICATION MODEL

$$K2 = (0.056)(QS)(F)^{-1}/(QS + 13.3) \quad (1)$$

$$R = 1+(1-(1+4N)^{0.5})/(2N) \quad (2)$$

where:

K2	= Second order decay rate (m^3/mg-yr)
QS	= Mean overflow rate (m/yr) = Z/T
F	= Inflow ortho P/total P ratio
Z	= Mean depth (m)
T	= Average HRT (yr)
R	= Total P retention coefficient = BMP efficiency
N	= (K2)(P)(T)
P	= Inflow total P (ug/L)

SOURCE: Reference 3

Other key factors to be considered in the pond design are the volume and area ratios. The volume ratio, VB/VR, is the ratio of the permanent pool storage (VB) to the mean storm runoff (VR). The area ratio, A/As, is the ratio of the contributing drainage area (A) to the permanent pool surface area (As). Both ratios are considered important in the design of the pond and are correlated with treatment efficiencies. Larger VBs and smaller VRs provide for increased retention and treatment between storm events. Low VB/VR ratios result in poor pollutant removal efficiencies. The eutrophication model indicates that the VB/VR ratio should equal 4.0 for maximum efficiency (Hartigan, 1988). However, design standards for the State of Maryland set VB/VR equal to 2.5 (Hartigan, 1988). The area ratio is also an indicator of pollutant removal efficiency. Data from previous studies, indicates that area ratios less than 100 typically have better pollutant removal efficiencies (MD, 1986). A VB/VR of 4.0 is equivalent to a 2 week HRT assuming an average of 100 storm events per year (Hartigan, 1988). This can be determined using the formula VB/[(VR)(N)] = HRT, where N is the average number of storm events per year and HRT is expressed in years. A different VB/VR ratio will change the HRT. For example, in Maryland a VB/VR ratio equal to 2.5 is equivalent to a 9 day HRT (Hartigan, 1988).

One way to increase the HRT is to increase the depth of the permanent pool. However, the permanent pool depth should not exceed 20 feet. The optimal depth ranges between 3 and 9 feet for most regions, given a 2 week HRT (Hartigan, 1988). Ponds with shallower depths will have shorted HRTs. It is important to maintain a sufficient permanent pool depth in order to prevent the resuspension of trapped sediments (NVPDC, 1992). Conversely, thermal stratification and anoxic conditions in the bottom layer might develop if permanent pool depths are too great. Stratification and anoxic conditions may decrease biological activity. Anoxic conditions may also increase the potential for the release of phosphorus and heavy metals from the pond sediments (NVPDC, 1992).

In general, pond designs are unique for each site and application. Ponds should always be designed to complement the natural topography (NVPDC, 1992). The pond should be constructed with adequate slopes and lengths. While, a length-to-width ratio is usually not used in the design of wet detention ponds for storm water quantity management, a 2:1 length-to-width ratio is commonly used when water quality is of concern. In general, high length-to-width ratios (greater than 2:1) will decrease the possibility of short-circuiting and enhance sedimentation within the permanent pool. Baffles or islands can also be added within the permanent pool to increase the flow path (Hartigan, 1988). Shoreline slopes between 5:1 and 10:1 are common and allow easy access for maintenance, such as mowing and sediment removal (Hartigan, 1988). In addition, wetland vegetation is difficult to establish and maintain on slopes steeper than 10:1. Ponds should be wedge-shaped so that flow enters the pond and gradually spreads out. This minimizes the potential for zones with little or no flow (Urbonas, 1993).

The design of the wet pond embankment is another key factor to be considered. Proper design and construction of the embankments will prolong the integrity of the pond structure. Subsidence and settling will likely occur after an embankment is constructed. Therefore, during construction the embankment should be overfilled by at least 5% (SEWPRC, 1991). Seepage through the embankment can also affect the stability of the structure. Seepage can generally be minimized by adding drains, anti-seepage collars and core trenches. The embankment side slopes can be protected from erosion by using minimum side slopes of 2:1 and by covering the embankment with vegetation or rip-rap. The embankment should also have a minimum top width of 6 feet to ease maintenance.

Normal flows will be discharged through the wet pond outlet, which consists of a concrete or corrugated metal riser and barrel. The riser is a vertical pipe or inlet structure that is attached to the base with a watertight connection. Risers are typically placed in or adjacent to the embankment rather than in the middle of the pond. This provides easy access for maintenance and prevents the use of the riser as a recreation spot (e.g., diving platform for kids) (Schueler, 1988). The barrel is a horizontal pipe attached to the riser that conveys flow under the embankment.

Typically, flow passes through an inverted pipe attached to the riser, as shown in Figure 1, with higher flows will pass through a trash rack installed on the riser. The inverted pipe should discharge water from below the pond water surface to prevent floatables from clogging the pipe and to avoid discharging the warmer surface water. Clogging of the pipe could result in overtopping of the embankment and damage to the embankment (NVPDC, 1992). Flow is conveyed through the near horizontal barrel and discharged to the receiving stream. Rip-rap, plunge pools, or other energy dissipators should be placed at the outlet to prevent scouring and minimize erosion. Rip-rap also provides a secondary benefit of reaeration of the pond discharges.

The design and construction of the riser and barrel should consider the design storm and the material of construction. Generally, the riser and barrel are sized to meet the storm water management design criteria (e.g., to pass a 2-year or a 10-year storm event). In many installations the riser and barrel are designed to convey multiple design storms (Urbonas, 1993). The riser and barrel should be constructed of reinforced concrete rather than corrugated metal pipe to increase the life of the outlet. The riser, barrel and base should also have sufficient weight to prevent flotation (NVPDC, 1992).

In most cases, emergency spillways should be included in the pond design. Emergency spillways should be sized to safely pass flows that exceed the design storm flows. The spillway prevents pond water levels from overtopping the embankment, which could cause structural damage the embankment. The emergency spillway should be located so that downstream buildings and structures will not be negatively impacted by a spillway discharges. The pond design should include a low flow drain, as shown in Figure 1. The drain pipe should be designed for gravity discharge and should be equipped with an adjustable gate valve.

MAINTENANCE

Wet detention ponds function more effectively when they are regularly inspected and maintained. Routine maintenance of the pond includes mowing of the embankment and buffer areas and inspection for erosion and nuisance (e.g., borrowing animals, weeds, odors) problems (SEWPRC, 1991). Trash and debris should be routinely removed to maintain an attractive appearance and also to prevent the outlet from becoming clogged. In general, wet detention ponds should be inspected after every storm event. The embankment and emergency spillway should also be routinely inspected for structural integrity, especially after major storm events. Embankment failure could result in severe downstream flooding.

When any problems are observed during routine inspections, necessary repairs should be made immediately. Failure to correct minor problems may lead to larger more expensive repairs or even pond failure. Typically, maintenance includes repairs to the embankment, emergency spillway, inlet and outlet, removal of sediment and control of algal growth, insects and odors (SEWPRC, 1991). Large vegetation or trees that may weaken the embankment should be removed. Periodic maintenance may also include the stabilization of the outfall area (e.g., add rip-rap) to prevent erosive damage to the embankment and the stream bank. In most cases sediments removed from wet detention ponds are suitable for landfill disposal. However, where available, on-site disposal od removed sediments will reduce maintenance costs.

COSTS

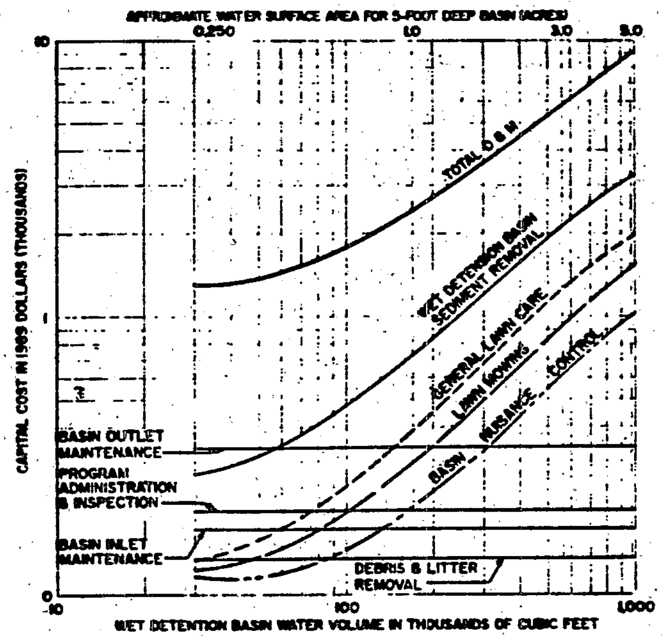
The total cost for a pond includes permitting, design and construction and maintenance costs. Permitting costs may vary depending on state and local regulations. Typically, wet detention ponds are less costly to construct in undeveloped areas than retrofitting into developed areas. This is due to the cost of land and the difficulty in finding suitable sites in developed areas. The cost of relocating of pre-existing utilities or structures is also a major concern in developed areas. The construction costs for wet detention ponds in 1989 for undeveloped areas are shown in Figure 2 below. These costs include mobilization and demobilization of heavy equipment, site preparation (e.g., clearing and excavation), site development (e.g., seeding and inlet construction) and contingencies (e.g., engineering and legal fees) (SEWPRC, 1991). Several studies have shown the construction cost of retrofitting a wet detention pond into a developed area may be 5 to 10 times the cost of constructing the same size pond in an undeveloped area.

Operation and maintenance costs in 1989 are presented in Figure 3 below (SEWPRC, 1991). Annual maintenance costs can generally be estimated at 3 to 5 percent of the construction costs (Schueler, 1992). Maintenance costs include the costs for regular inspections of the pond embankments, grass mowing, nuisance control, debris and liter removal, inlet and outlet maintenance and inspection, and sediment removal and disposal. Sediment removal costs can be decreased by as much as 50 percent if an on-site disposal areas are available (SEWPRC, 1991).

ENVIRONMENTAL IMPACTS

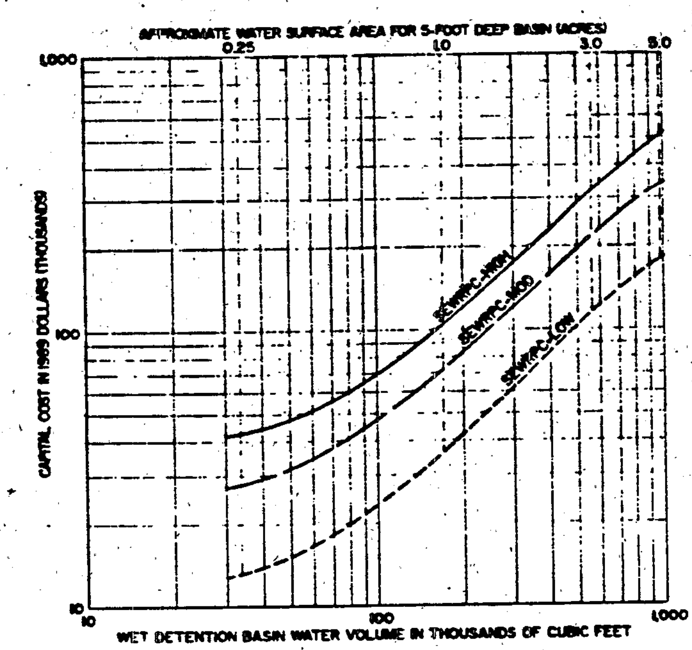
Wet detention ponds provide both storm water quantity and quality benefits. Benefits obtained from the use of wet detention ponds include decreased potential for downstream flooding and stream bank erosion. Water quality is also improved due to the removal of suspended solids, metals, and dissolved nutrients. In general, the positive impacts from a wet detention ponds will exceed any negative impacts from a pond, assuming the pond is properly designed and maintained.

TABLE 3: CONSTRUCTION COSTS (1989)



SOURCE: Reference 4

TABLE 4: OPERATIONS AND MAINTENANCE COSTS (1989)



SOURCE: Reference 4

However, wet detention ponds that are improperly designed, sited or maintained may have potential adverse affects on water quality, groundwater, cold water fisheries, or wetlands. Improperly designed or maintained ponds may result in stratification and anoxic conditions that can promote the resuspension of solids and the release of nutrients and metals from the trapped sediments. During construction, precautions should be taken to prevent damage to wetland areas. Ponds should also not be sited in areas where warm water discharges from the pond will adversely impact cold water fishery. The potential groundwater contamination should be carefully evaluated. However, studies to date indicate that wet detention ponds do not significantly contribute to groundwater contamination (Schueler, 1992).

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