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MUNICIPAL WASTEWATER MANAGEMENT FACT SHEETS: STORM WATER BEST MANAGEMENT PRACTICES

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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; 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. The document does not provide sufficient information to design BMPs, but does provided sufficient information to compair alternatives. In some cases, the information represents new technology or new application of existing technology and is base on very limited data. 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. This document incorporates and superseeds previous storm water best management practice fact sheets (EPA 832-F-93-013, September 1993 and Addendum to EPA 832-F-93-013, September 1994) . Updates to this set of fact sheets and development of additional sets is dependent upon continued resources being available.

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. Treatment BMPs include both in-line ans off-line applications. 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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STORM WATER BMP: AIRPLANE DEICING FLUID RECOVERY SYSTEMS

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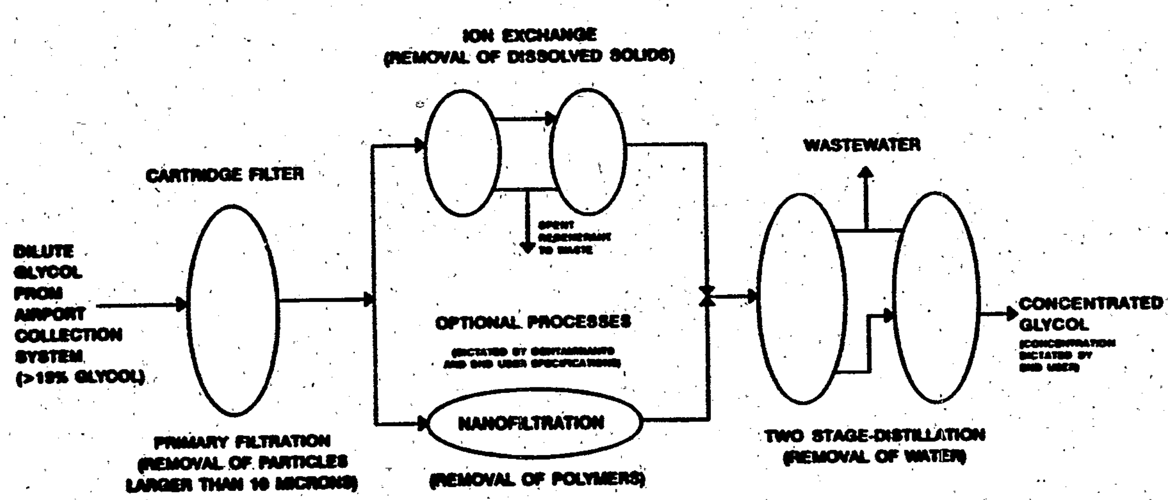
DESCRIPTION

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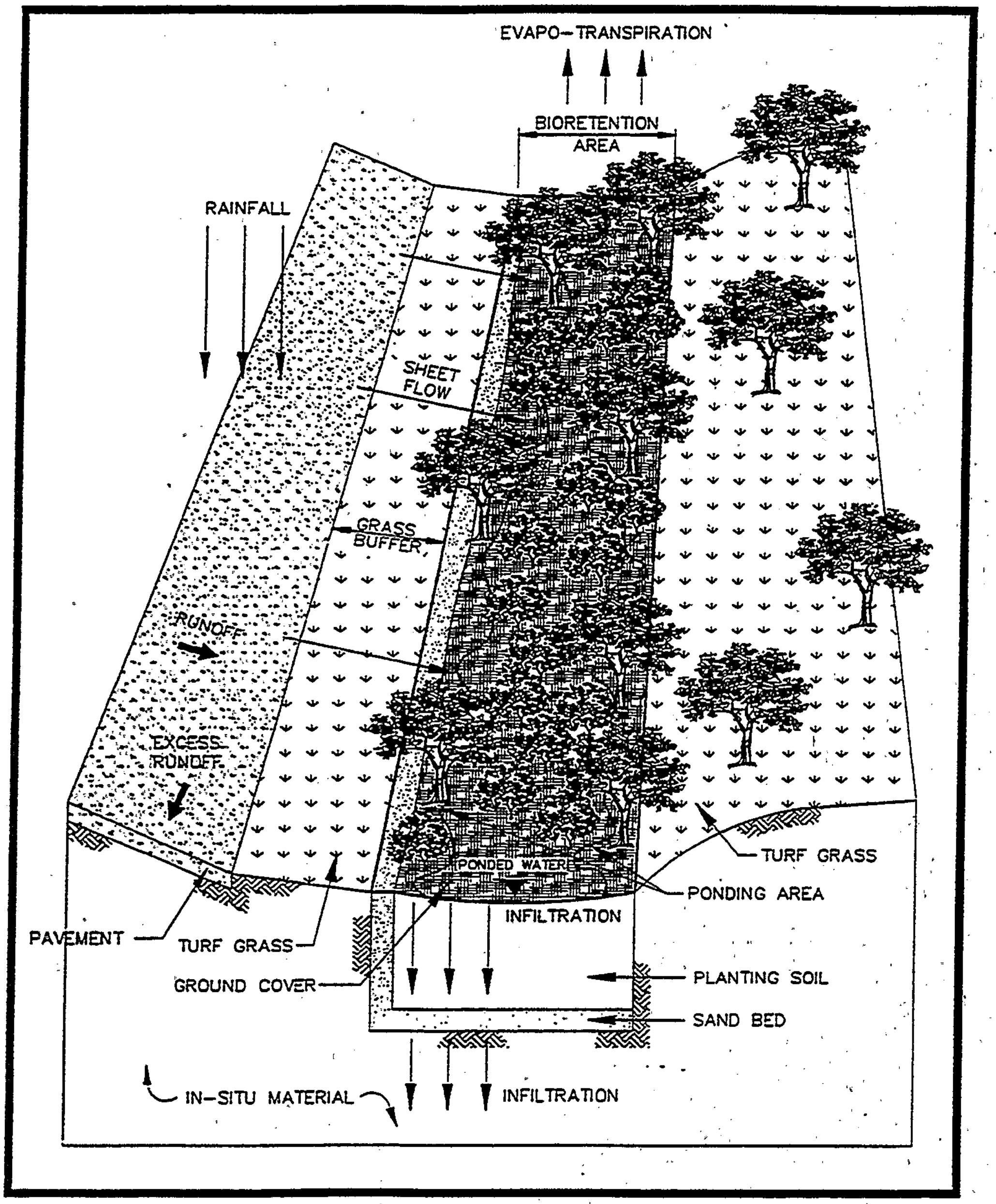
This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC, 20460

STORMWATER BMP:
BIORETENTION

DESCRIPTION

Bioretention is a recently developed best management practice (BMP) developed by the Prince George's County, Maryland Department of Environmental Resources (PGDER). The BMP utilizes soils and plants to remove pollutants from stormwater runoff. As shown in Figure 1, runoff is conveyed as

FIGURE 1 BIORETENTION AREA



Source: PGDER, 1993.

sheet flow to the BMP, which consists of a grass buffer strip, sand bed, ponding area, organic layer or mulch layer, planting soil, and plants. Runoff first passes over a sand bed, which slows the velocity and evenly distributes the runoff over the ponding area. Runoff also infiltrates the sand bed, which adds to the infiltration capacity of the bioretention area. After runoff passes over or infiltrates the sand bed it enters the ponding area. The ponding area is formed by depressing the surface organic layer and/or ground cover and the underlying planting soil. Water is ponded to a depth of 6 inches and gradually infiltrates the bioretention area or is evapotranspired. The grading of the bioretention area is done so that excess runoff is diverted away from the BMP. Stored water in the bioretention area planting soil exfiltrates over a period of days into the underlying soils of the BMP.

COMMON MODIFICATIONS

The City of Alexandria, Virginia has modified the design to include an underdrain within the sand bed to collect the infiltrated water and discharge it to a downstream sewer system. Underdrains were required due to impervious subsoils and marine clays. This modified design makes the bioretention area act more as a filter that discharges treated water than an infiltration device. The BMP can also be modified to include or not include a sand bed. The benefit of using a sand bed is the reduction in velocity and infiltration achieved with the bed. Design modifications are also being reviewed to potentially utilize both aerobic and anaerobic zones in the BMP. The anaerobic zone will promote denitrification.

CURRENT STATUS

Bioretention has been used successfully at urban and suburban areas in Prince George's County, Maryland (MD), Montgomery County, MD, Baltimore County, MD, and Prince William County, Virginia. The first system was installed nearly four years ago (1992). The BMP is planned for installation in Alexandria, Virginia and locations in North Carolina.

APPLICATIONS

Bioretention typically provides stormwater treatment for impervious surfaces at commercial, residential, and industrial areas. Three prime locations where the BMP could be used are at median strips, parking lot islands, and in swales. They are usually best used at locations that are upland from inlets that receive sheet flow from graded areas and at areas that will be excavated. Sheet flow should be conveyed to the BMP to minimize erosive conditions and to maximize treatment effectiveness. Low environmental impacts to a site are desired. Therefore, construction of bioretention areas best suited to sites where grading or excavation will occur so that the bioretention area can be readily incorporated in the site plan. Bioretention areas should be used in stabilized drainage areas to minimize the sediment loading to the BMP.

LIMITATIONS

Bioretention is not an appropriate BMP at locations where the water table is within 6 feet of the ground surface and when the surrounding soil stratum is unstable. In cold climates there is the potential for the soil to freeze and prevent runoff from infiltrating into the planting soil. The BMP is also not recommended for areas with slopes greater than 20 percent or where mature tree removal will be required. Clogging may be a potential problem, particularly if the BMP receives runoff with high sediment loads.

PERFORMANCE

Stormwater pollutant removal in bioretention is attributed to physical and biological processes that occur in the plants and soils of the BMP. These processes include adsorption, filtration, plant uptake, microbial activity, decomposition, sedimentation and volatilization.

Adsorption is the process where pollutants attach to soil (e.g., clay) or vegetation surfaces. Adequate contact time between the surface and pollutant must be provided for in the design of the system for this removal process to occur. Therefore, the infiltration rate of the soils must not exceed those specified or pollutant removal may decrease. Pollutants removed by adsorption include metals, phosphorus, and some hydrocarbons.

Filtration occurs as runoff passes through the bioretention area media, such as the sand bed, ground cover and planting soil. The media trap particulate matter and allows water to pass through. The filtering effectiveness of the bioretention area may potentially decrease over time. Common particulates removed from stormwater include particulate organic matter and suspended solids.

Biological processes that occur in wetlands result in pollutant uptake by plants and microorganisms in the soil. Plant growth is sustained by the uptake of nutrients from the soils. Microbial activity within the soil also contributes to the removal of nitrogen and organic matter. Nitrogen is removed by nitrifying and denitrifying bacteria and aerobic bacteria are responsible for the decomposition of the organic matter (e.g., petroleum). Microbial processes require oxygen and can result in depleted oxygen levels if the bioretention area is not adequately aerated.

Sedimentation occurs in the swale or ponding area as the velocity slows and suspended solids fall out of suspension. Volatilization also plays a role in pollutant removal. Pollutants such as oils, hydrocarbons, and mercury can be removed from the wetland via evaporation or by aerosol formation under windy conditions.

Data is not available on the removal effectiveness of bioretention; however, results from performance studies for infiltration BMPs can be used due to the similarities in the BMPs. The microbial activity and plant uptake occurring in the bioretention area will likely result in higher removal rates than those determined for infiltration BMPs, as shown in Table 1. As shown, the BMP could potentially have greater than 90 percent removal rates for total suspended solids, organics, metals, and bacteria. Excessive pollutant loadings (e.g., suspended solids) may exceed the removal capabilities of the bioretention area.

TABLE 1 ESTIMATED PERFORMANCE OF BIORETENTION (1)

Pollutant	Removal Rate
Total Suspended Solids	90 %
Total Phosphorus	60 %
Total Nitrogen	60 %
Organics	90 %
Metals	90 %
Bacteria	90 %

(1) Source: Schueler, 1987, 1992.

DESIGN CRITERIA

Design details have been specified by the Prince George's County DER in a document entitled *Design Manual for Use of Bioretention in Stormwater Management* (PGDER, 1993). The specifications were developed after extensive research on soil adsorption capacities and rates, water balance, plant pollutant removal potential, plant adsorption capacities and rates, and maintenance requirements. A case study was performed using the specifications at three commercial sites and one residential site in Prince George's County, Maryland.

Each of the components of the bioretention area is designed to perform a specific function. The function of the grass buffer strip is to reduce incoming runoff velocity and filter particulates from the runoff. The sand bed also reduces the velocity and provides some particulate filtration, as well as evenly spreading the flow over the bioretention area. Aeration and drainage of the planting soil is provided by the 1 foot deep sand bed. The ponding area provides a temporary storage location for runoff prior to its evaporation or infiltration. Particulates that had not been previously filtered out by the grass filter strip or the sand bed settle within the ponding area. The organic or mulch layer also filters pollutants and provides an environment conducive to the growth of microorganisms which degrade petroleum based products and other organic material. This layer acts as the leaf litter in a forest and prevents the erosion and drying of underlying soils. Planted ground cover and mulch reduce the potential for erosion, with mulch being slightly less effective than planted ground cover. The maximum sheet flow velocity prior to erosive conditions is 1 ft/sec and 3 ft/sec for planted ground cover and mulch, respectively. The clay in the planting soil provides adsorption sites for hydrocarbons, heavy metals, nutrients and other pollutants. Storage of stormwater is also provided by the voids in the planting soil. The stored water and nutrients in the water and soil are then available to the plants for uptake.

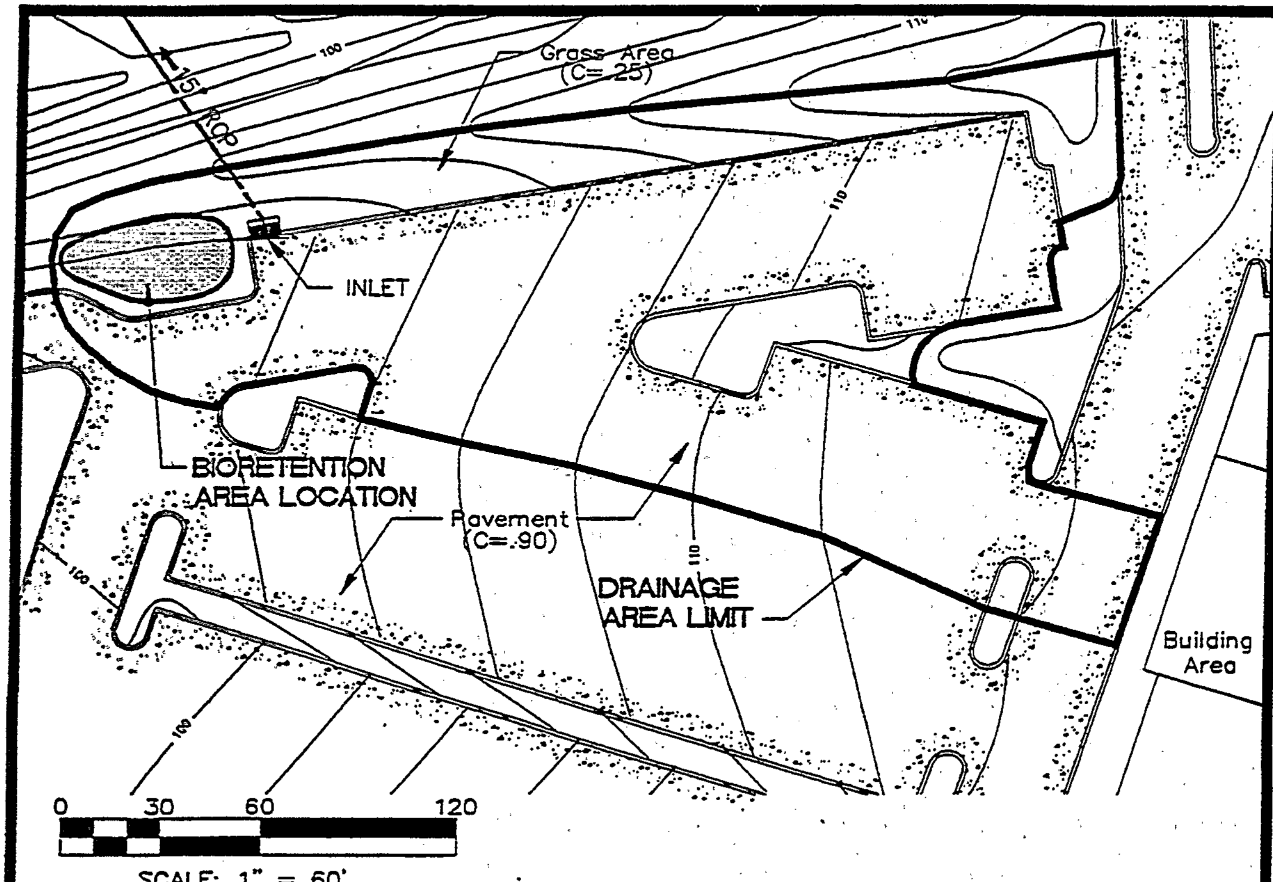
The layout of the bioretention area is determined after site constraints such as location of utilities, underlying soils, existing vegetation, and drainage are considered. The existence of utilities (e.g., electric or gas) which would be costly to relocate may limit the feasibility of a site. Sites with loamy sand soils are especially appropriate for bioretention because the excavated soil can be backfilled and used as the planting soil, thus eliminating the cost of importing planting soil. An unstable surrounding soil stratum (e.g., Marlboro Clay) and soils with a clay content of greater than 25 percent may preclude the use of bioretention, as would a site with slopes greater than 20 percent or a site with mature trees that would be removed during construction of the BMP. Bioretention can be designed to be off-line or on-line of the existing drainage system. The "first flush" of runoff is diverted to the off-line system. On-line systems capture the first flush but that volume of water will likely be washed out by subsequent runoff.

The size of the drainage area for one bioretention area should be between 0.25 and 1 acre. Multiple bioretention areas may be required for larger drainage areas. The maximum drainage area for one area is determined by the amount of sheet flow generated from the 10-year storm. Flows greater than 5 cfs may potentially erode stabilized areas. In Maryland, a flow of 5 cfs generally occurs with a 10-year storm at one-acre commercial or residential sites. The designer should determine the potential for erosive conditions at the site.

The size of the bioretention area is a function of the drainage area and the runoff generated from the area. The size should be 5 to 7 percent of the drainage area multiplied by the rational method runoff coefficient, "c", determined for the site. The 5 percent specification applies to a bioretention area that includes a sand bed and 7 percent applies to an area designed without the sand bed. An example of sizing a facility is shown in Figure 2. Sizing specifications are based on 0.5 inches to 0.7 inches of precipitation over a 6-hour period, which is the mean storm event for the Baltimore-Washington area, infiltrating into the bioretention area. Other areas with a different mean storm event will need to account for that in the design of the BMP.

Recommended minimum dimensions of the bioretention area are 15 feet wide by 40 feet in length. The minimum width allows enough space for a dense randomly distributed area of trees and shrubs to become established that replicates a natural forest and creates a microclimate. This enables the bioretention area to tolerate the effects of heat stress, acid rain, runoff pollutants, and insect and disease infestations which landscaped areas in urban settings typically are unable to tolerate. The preferred width is 25 feet, with a length of twice the width. Any facilities with widths greater than 20 feet should have a length of twice the width. This length requirement promotes the distribution of flow and decreases the chances of concentrated flow.

FIGURE 2 BIORETENTION AREA SIZING



PLAN VIEW

BIORETENTION AREA
SIZING COMPUTATION

DEVELOPMENT	AREA (SQ. FT.)	"C"* FACTOR	C x AREA
PAVEMENT	23,800	0.90	21,400
GRASS	10,100	0.25	2,500
TOTALS	33,900		23,900

BIORETENTION AREA SIZE

1. WITH SAND BED (5% SUM OF C x AREA)
   = .05 x 23,900 = 1,195 OR SAY 1,200 SQ.FT.

2. WITHOUT SAND BED (7% SUM OF C x AREA)
   = .07 x 23,900 + 1,673 OR SAY 1,700 SQ. FT.

*SEE CHAPTER IV, PRINCE GEORGES COUNTY STORMWATER MANAGEMENT MANUAL

Source: PGDER, 1993

The maximum ponding depth of the bioretention area has been determined to be 6 inches. This depth provides for adequate storage and prevents excessive periods of time for standing water. Water left to stand for longer than four days restricts the type of plants that can be used due the water tolerance of most plants. Mosquitoes and other insects may also start to breed if water is standing for longer than four days.

The appropriate planting soil should be backfilled into the excavation bioretention area. Planting soils should be sandy loam, loamy sand, or loam texture and have a clay content ranging from 10 to 25 percent. The soil should have infiltration rates greater than 0.5 inches per hour (in/hr), which is typical of sandy loams, loamy sands, or loams. Silt loams and clay loams generally have rates of less than 0.27 in/hr. The pH of the soil should be between 5.5 and 6.5. Pollutants (e.g., organic nitrogen and phosphorus) can be adsorbed by the soil and microbial activity can flourish within this pH range. Other requirements for the planting soil are a 1.5 to 3 percent organic content and a maximum 500 ppm concentration of soluble salts. In addition, criteria for magnesium, phosphorus, and potassium are 35 lbs/acre, 100 lbs/acre, and 85 lbs/acre, respectively. Soil tests should be performed for every 500 cubic yards of planting soil with the exception of tests run for pH and organic content, which is only required once per bioretention area.

A minimum planting soil depth of 4 feet should be used in a bioretention facility. This depth will provide adequate soil for the plants root system to become established in and prevent plant damage due to severe wind. Four feet of soil also provides adequate moisture capacity. To obtain the 4 foot depth, most sites will require excavation. Depths of greater than 4 feet may require additional construction practices (e.g., shoring measures). Planting soil should be placed in 18 inches or greater lifts and lightly compacted until the desired depth is reached.

The bioretention area should be vegetated to resemble a terrestrial forest community ecosystem, that is dominated by trees and has discrete soil zones. A terrestrial forest community also has a mature canopy and a distinct sub-canopy of understory trees, a shrub layer and herbaceous ground covers. Three species of both trees and shrubs are recommended at a rate of 1,000 trees and shrubs per acre. For example, a 15' by 40' bioretention area (600 ft^2 or 1.4 percent of an acre) would require 14 trees and shrubs. The tree to shrub planting ratio should be 2:1 to 3:1. On average, the trees should be spaced 12 feet apart and the shrubs should be spaced 8 feet apart. In the metropolitan Washington, D.C. area trees and shrubs should be planted from mid-March through the end of June or from mid-September through mid-November. Planting periods in other areas of the US will vary. Vegetation should be watered at the end of each day for fourteen days following its planting.

Native species that are tolerant to pollutant loads and varying wet and dry conditions should be used in the bioretention area. These species can be determined from several published sources, including *Native Trees, Shrubs, and Vines for Urban and Rural America* (Hightshoe, 1988). The designer should assess aesthetics, site layout, and maintenance requirements when selecting plant species. Adjacent non-native invasive species should be identified and the designer should take measures (e.g., provide a soil breach) to eliminate the threat of these species invading the bioretention area. Regional landscaping manuals should be consulted to ensure that the planting of the bioretention area meets the landscaping requirements established by the local authorities.

The optimal placement of vegetation within the bioretention area should be evaluated by the designer. Plants should be placed randomly to replicate a natural forest. Shade and shelter from the wind will be provided to the bioretention area if the designer places the trees on the perimeter of the area. Damaging flows to trees and shrubs can be minimized if they are placed away from the path of the incoming runoff. Certain species that are more tolerant to cold winds (e.g., evergreens) should be placed in areas of the site where these winds typically enter the site.

After placing the trees and shrubs, the ground cover and/or mulch should be established. Ground cover such as grasses or legumes can be planted during the spring of the year. There are no restraints to the timing of mulch placement, except that it should immediately follow tree and shrub planting. Two to three inches of commercially available fine shredded hardwood mulch or shredded hardwood chips should be applied to the bioretention area to provide protection from erosion. Depths greater than 3 inches should not be applied because it would negatively impact the cycling of carbon dioxide and oxygen between the soil and the atmosphere. The mulch should be aged for at least six months, (one year is optimal), and applied uniformly over the site.

MAINTENANCE

Recommended maintenance for a bioretention area includes inspection and repair or replacement of the BMP components. Trees and shrubs should be inspected twice per year to determine their health and remove and replace any dead or severely diseased vegetation. Diseased vegetation that can be treated should be done on an as needed basis. Pruning and weeding may also be necessary to maintain the appearance of the BMP.

Mulch replacement is recommended when erosive conditions are evident or when the aesthetics of the bioretention area are declining. Spot mulching may be adequate when there are random void areas; however, once every two to three years the entire area may require mulch replacement. This activity should be performed during the spring. The previous layer of mulch should be removed prior to application of the replacement mulch.

The application of an alkaline product, such as limestone, is recommended one to two times per year due to increasing acidity of the soil that results from slightly acidic precipitation and runoff. Prior to applying the limestone, the soils and organic layer should be tested to determine the pH and determine the quantity of limestone required. Testing should also be performed to determine concentrations of heavy metals and other toxic substances in the soil. Forest buffers and grass swales, which accept similar sources of runoff as the bioretention area, tend to accumulate toxins and heavy metals within five years of installation. This suggests the possibility of a similar accumulation at a bioretention area. Soil replacement may be required when toxic levels of heavy metals or other pollutants are reached which impairs plant growth and the effectiveness of the BMP (PGDER, 1993).

COSTS

Construction cost estimates for a bioretention area are slightly greater than the required landscaping for a new development. Recently constructed 400 ft^2 bioretention areas in Prince George's County cost approximately $500. These units are rather small and are on the low side for cost estimation purposes particularly if a larger unit is required. The cost estimate includes the cost for excavating 2 to 3 feet and vegetating the site with 1 to 2 trees and 3 to 5 shrubs. The estimate does not include the cost for the planting soil. Purchasing soils will increase the cost for a bioretention area. Retrofitting a site typically has higher costs with an average cost of $6,500 per bioretention area. The higher costs are attributed to the demolition of existing concrete, asphalt, and/or existing structures and the replacement of fill material with planting soil. Plans for retrofitting a commercial site in Maryland (Kettering Development) was estimated at $111,600, which included 15 bioretention areas. The final costs for the retrofit were much lower due to only six bioretention areas being constructed.

The use of bioretention can decrease the cost for stormwater conveyance systems at a site. A medical office building in Maryland was able to reduce the required amount of storm drain pipe from 800 to 230 feet with the use of bioretention. The drainage pipe costs were reduced by $24,000 or 50 percent of the total drainage cost for the site (PGDER, 1993). Landscaping costs that would be required at a development regardless of the installation of the bioretention area should also be considered when determining the net cost of the BMP.

The operation and maintenance costs for a bioretention facility will be comparable to typical landscaping required for a site. Costs beyond the normal landscaping fees will include the cost for testing the soils.

ENVIRONMENTAL IMPACTS

Bioretention provides stormwater treatment that enhances the quality of downstream water bodies. Runoff is temporarily stored in the BMP and released over a period of four days to the receiving water. The BMP is also able to provide shade and wind breaks, absorb noise, and improve an area's landscape.

REFERENCES

1. Prince George's County Department of Environmental Resources (PGDER), 1993. Design Manual for Use of Bioretention in Stormwater Management. Division of Environmental Management, Watershed Protection Branch. Landover, MD.

2. Bitter, S., and J. Keith Bowers, 1994. Bioretention as a Water Quality Best Management Practice. Watershed Protection Techniques, Vol. 1, No.3, Fall 1994, Silver Spring, MD.

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4. Reed, P.B., Jr, 1988. National List of Species That Occur in Wetlands: Northeast. United States Fish and Wildlife Service, St. Petersburg, Florida.

5. Schueler, T.R., 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practices. Metropolitan Washington Council of Governments.

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STORM WATER BMP: CATCH BASIN CLEANING

EPA MTB
Office of Wastewater Enforcement & Compliance
MUNICIPAL TECHNOLOGY BRANCH

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.

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

STORM WATER BMP: COVERINGS

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.

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STORM WATER BMP: DUST CONTROL

EPA MTB
Office of Wastewater Enforcement & Compliance
MUNICIPAL TECHNOLOGY BRANCH

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

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

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.

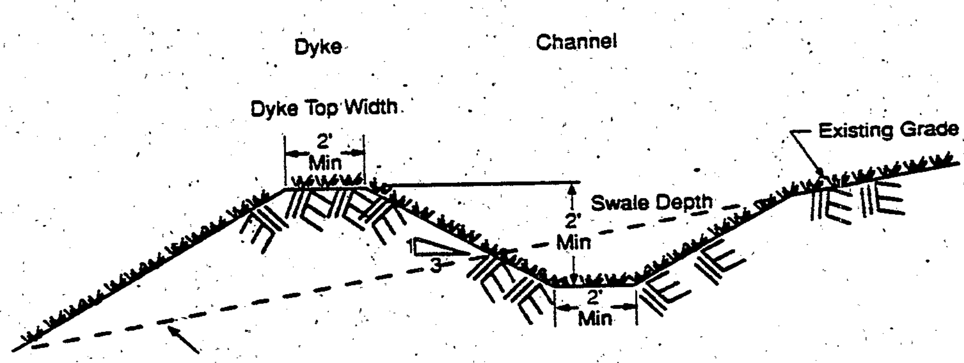
PERFORMANCE

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.

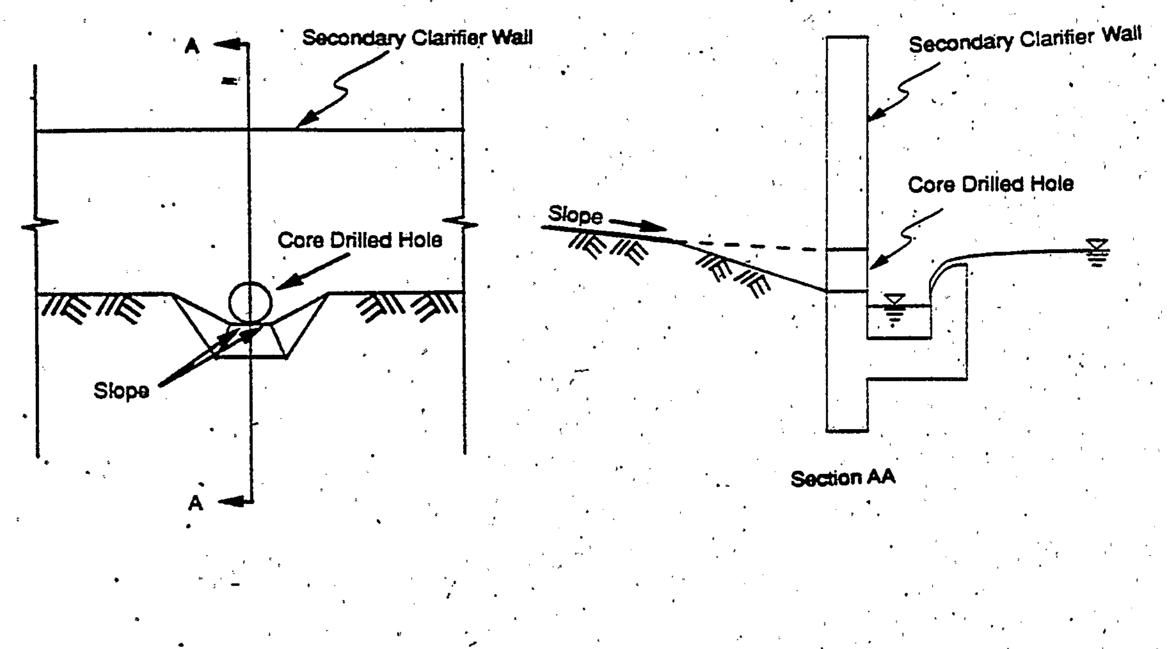


SOURCE: Reference 3.

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.



SOURCE: Reference 1.

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.

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STORMWATER BMP: HIGHWAY ICE AND SNOW REMOVAL AND MINIMIZATION OF ASSOCIATED ENVIRONMENTAL EFFECTS FROM THESE PROCEDURES

INTRODUCTION

The United States is critically dependent on the nation's road system to support the rapid, reliable movement of people, goods, and services. The widespread expectation holds that even in the face of winter storms, roads and highways will be maintained to provide safe travel conditions. In many states, this requires substantial planning, training, manpower, equipment, and material resources to clear roads and streets throughout the winter.

The dependency on deicing chemicals has increased since the 1940s and 1950s to provide "bare pavement" for safe and efficient winter transportation. Sodium chloride (salt) is one of the most commonly used deicing chemicals. Concern about the effects of sodium chloride on the nation's environment and water quality has increased with this chemical usage. Automobile and highway bridge deck corrosion has also become a concern. However, in most cases sodium chloride is the most cost effective deicing chemical. Such concerns have led to major research efforts by the Strategic Highway Research Program (SHRP), the highway community, industry, government, and academia. This ongoing research is exploring many different areas in an effort to maintain the safest roads possible in the most economical way while protecting the environment.

This fact sheet summarizes research addressing water pollution and associated effects from deicing chemicals, and describes the methods used to control snow and ice on roadways while minimizing impacts on the environment. Due to the broad nature of this topic, sources for research and alternative methods are listed and can be referenced for more detail. This fact sheet emphasizes methods and practices for snow removal which are feasible and cost effective for local governments to implement consistent with sound environmental quality goals.

BACKGROUND

Salt was first used on roads in the United States for snow and ice control in the 1930s (Salt Institute, 1994). Beginning in the late 1940s and 1950s, the "bare pavement" policy was gradually adopted by highway agencies as the standard for pavement condition during inclement weather providing safer travel conditions on roadways. The "bare pavement" policy became a useful concept for roadway maintenance because it was a simple and self-evident guideline for highway crews. However, this policy should be implemented with the application of the minimum amount of salt needed rather than the maximum (Lord, 1988). A common perception that "more is better" led to practices of high application rates of salt. Dispersion of city populations into suburbs, higher travel speeds, and growing dependence upon automobiles for commuting and commerce increased the need for snow and ice removal for safer roadways (Lord, 1988). In the 1960s, the use of salt as a deicing chemical became widespread in the United States because it is readily available, it is effective on ice and snow, and it is the lowest cost alternative (Salt Institute, 1994).

In the late 1950's, damage to roadside sugar maples (a salt intolerant species) in New England gave rise to concern about the widespread use of salt. Shortly thereafter, contamination to drinking water from wells located near unprotected salt storage areas heightened this concern (Lord, 1988). Runoff of road salts also became recognized as causing additional environmental damage in many areas. Other adverse effects of the increased use of salt included the pitting and "rust out" of automobiles and corrosion of highway structures, especially bridge decks (Lord, 1988).

These environmental concerns have spawned a number of research programs. The goal of this research has been to minimize the environmental effects of deicing while still providing a cost effective means of clearing roadways for safe travel conditions. Early in the 1960s, research began on alternative deicing chemicals, reduced chemical use, improved operational practices, pavement heating, pavement modification, and mechanical approaches (Lord, 1988). More recently, a "Snow and Ice Control" study was conducted by the Strategic Highway Research Program (SHRP). SHRP is a unit of the National Research Council that was authorized by Section 128 of the Surface Transportation and Uniform Relocation Assistance Act of 1987 (SHRP-H-381, 1994). The snow and ice control research included five major initiatives: snowplows, snow fences, road weather information systems, pretreatment, and deicing chemicals (SHRP, 1991).

INITIATIVES TO CONTROL SNOW AND ICE ON ROADWAYS WHILE MINIMIZING ASSOCIATED ENVIRONMENTAL EFFECTS

Improved Operational Practices

Clearing roadways after winter storms accounts for a large portion of the highway maintenance budget for many northern states. According to the Salt Institute's 1991 *Snowfighters Handbook*, snow removal in 33 snow belt states accounted for 16.2 percent of total maintenance costs and 3.6 percent of all highway expenditures (Salt Institute, 1991). To ensure public safety, minimize environmental effects, and minimize costs, a well planned and operated snow and ice removal program is essential.

To aid highway management personnel in improving operational practices, the Salt Institute initiated a "sensible salting" program in 1967 (Lord, 1988). These guidelines have evolved with technology to include the following: planning; personnel training; equipment maintenance; spreader calibration; proper storage; proper maintenance around chemical storage areas; and environmental awareness (Salt Institute, 1994). Further information on the "sensible salting" program can be obtained from the Salt Institute located in Alexandria, Virginia. While all of these guidelines reflect key concerns, proper storage is considered one of the most effective in source control of deicing chemicals (EPA, 1974).

In a 1988 paper by Lord, the estimated annual loss of uncovered stockpiled salt in the United States due to rainfall was 400,000 tons, which is approximately 5 percent of the 8 million tons of salt used annually in the United States. An estimate of $30 per ton of salt equates to a monetary loss of $12 million dollars each winter (Lord, 1988). Rock salt may be purchased in bulk for approximately $15 to $20 per ton. Including transportation, these costs increase to $35 to $70 per ton (Lord, 1988). Monetary loss calculations by Lord used a unit cost estimate for salt of $30 per ton which is between estimates including and excluding transportation. Guidelines for siting and design of deicing chemical storage facilities are provided in the *Manual for Deicing Chemicals: Storage and Handling* (EPA-670/2-74-033, 1974).

Another source, the Regional Groundwater Center (1995), estimated that 10 million tons of salt are used each winter in the United States to melt snow and ice on roads and surface streets (Regional Groundwater Center, 1995, Salt Institute, 1994). The cost for salt is currently estimated at $17 to $20 per ton excluding transportation costs (Jesperson, 1995). To minimize environmental impacts associated with briny runoff due to rain and an uncovered stockpile of salt, proper storage facilities must be implemented.

One of the most effective measures for reducing chemical application has been the use of a calibrated spreader using the optimal application rate. Salt application rates range from 300 to 800 pounds per two-lane mile, depending on road, storm, and temperature conditions (Salt Institute, 1994). Automatic controls on spreaders are recommended to ensure a consistent and correct application rate. The spreader should be calibrated prior to and periodically during the snow season, regardless of whether automatic or manual controls are used. Uncalibrated controls and poor maintenance are often responsible for excessive salt use (Salt Institute, 1994). Guidelines for the calibration of spreaders and determination of application rates are given in the Salt Institute's *Snowfighters Handbook* (1991) and in the EPA document entitled *Manual for Deicing Chemicals: Application Practices* (EPA-670/2-74-045, 1974).

Road Weather Information Systems

The United States and Canada spend over $2 billion dollars each year on snow and ice control (SHRP, 1993). In an effort to reduce these costs and maximize efforts, the SHRP sponsored research using road weather information systems (RWIS) for highway snow and ice control. Components of the RWIS include meteorological sensors, pavement sensors, site-specific forecasts, temperature profiles of roadway, other available weather information (including a weather advisor), communications, and planning (SHRP, 1993).

The RWIS can be used to maximize icing and plowing efforts by pinpointing and prioritizing roadways which need attention. It is also designed to eliminate unnecessary call-outs and provide better scheduling of crews based on knowledge of the probable extent and severity of the winter storms. Research indicated that the use of the RWIS technologies can improve efficiency and effectiveness as well as reduce the costs of highway winter maintenance practices (SHRP, 1993). It was concluded in this report that road weather information system technology has the potential for improving service. This conclusion led to the recommendation that every agency that regularly engages in snow and ice control should consider acquiring some form of road weather information systems; at a minimum, forecast services should be used. The SHRP also pointed out that additional research beyond the scope of the original RWIS project would be helpful (SHRP, 1993). Additional information about RWIS and intelligent and localized weather prediction are provided in the following SHRP manuals: *Road Weather Information Systems, Volumes 1 and 2* (SHRP-H-350 and SHRP-H-351); and *Intelligent and Localized Weather Prediction* (SHRP-H-333).

Alternative Deicing Chemicals

The most commonly used salts for deicing are sodium chloride (NaCl) and calcium chloride (CaCl) (Salt Institute, 1994). Approximately 10 million tons of salt are used each year at a cost of approximately $17 to $20 a ton (Jesperson, 1995). The eastern and north-central sectors of the country use more than 90 percent of this salt each year (Lord, 1988). Salt has proven to be a very effective and feasible deicing chemical. However, the importance of snow and ice removal programs, public safety, economic concerns, and environmental factors have led to research utilizing alternative deicing chemicals.

An acceptable alternative to salt as a deicer must have an effective melting range similar to salt, lack detrimental effects, and be cost-comparable. Some alternative deicers evaluated include formamide, urea, urea-formamide mixture, tetrapotassism phosphate (TKPP), ethylene glycol, ammonium acetate, and calcium magnesium acetate (Lord, 1988). The only alternative that warranted further consideration was calcium magnesium acetate (CMA). CMA is made from delometric limestone treated with acetic acid. While CMA does not overcome all the undesirable characteristics of salt, it is an effective deicing chemical (although more material does need to be applied to result in the same deicing achieved with salt). Since CMA has less potential to effect the environment and is not as corrosive as salt, it is a frequently used deicing chemical. However, the cost of CMA was estimated to exceed salt by a factor of 10 to 20 (Lord, 1988). Efforts have been made to find a more effective production technology to lower the cost of CMA, but these efforts have had limited success (Lord, 1988). Alternative deicers can cost anywhere from $200 to $700 a ton (Jesperson, 1995). Therefore, salt is still the most cost effective deicing agent. Another study performed by the Michigan Department of Transportation also found salt to be the most cost effective deicing agent of those evaluated. Those evaluated included sodium chloride (road salt), CMA, CMS-B (also known as Motech), CG-90 Surface Saver (a patented corrosion-inhibiting salt), Verglimit (patented concrete surface containing calcium chloride pellets), and calcium chloride (MDOT, 1993).

In 1992, the SHRP published a handbook to standardize testing procedures for evaluating deicing chemicals (SHRP, 1992). Parameters evaluated include fundamental properties (e.g., ice melting potential, fundamental thermodynamic factors), physicochemical characteristics, deicing performance (e.g., ice melting, ice penetration, ice undercutting), materials compatibility, and additional engineering parameters. This handbook is a valuable tool for the on-going research and technology of evaluating deicing chemicals. Additional information on these testing procedures is provided in the *Handbook of Test Methods for Evaluating Chemical Deicers* (SHRP-H-332, 1992).

Pretreatment

Limited experience (mainly in Scandinavian and other European countries) has shown that applying a chemical freezing-point depressant on a highway pavement prior to, or very shortly after, the start of accumulation of frozen precipitation minimizes the formation of an ice-pavement bond (SHRP, 1994). Liquid salt solution has been practiced in Scandinavia and has proven successful for pretreatment (SHRP, 1994). The anti-icing or pretreatment practice reduces the task of clearing the highway and requires smaller chemical amounts than are generally required under conventional deicing practices (e.g., applying after snow or ice have begun to accumulate). When properly implemented, pretreatment practices may reduce costs and be more effective than conventional practices. However, most state highway agencies generally have not adopted pretreatment due to uncertainty regarding how to implement this practice and which conditions most favor it. Other concerns with pretreatment practices include the imprecision with which icing events can be predicted, the uncertainty about the condition of the pavement surface, and the public's perception of wasted chemicals. Some early attempts to utilize pretreatment practices in the United States have failed because of these uncertainties (SHRP, 1994).

The technological improvements in weather forecasting and in assessment of pavement surface conditions, as previously mentioned, offer the potential for successful implementation of pretreatment. Research during the winters of 1991-92 and 1992-93 by the SHRP indicated that a 40 percent and 62 percent reduction, respectively, in chemical usage was possible using pretreatment (SHRP, 1994). The success of pretreatment depends on accurate RWIS, a technology which is still evolving. Development of spreaders specifically designed or retrofitted to distribute prewetted solid material or liquid chemicals, calibration and evaluation of spreaders, training of maintenance personnel, and effective communication are also items that need further attention to ensure the success of a pretreatment program (SHRP, 1994). Additional information on pretreament is available in the SHRP manual entitled, *Development of Anti-Icing Technology* (SHRP-H-385, 1994).

Mechanical and Design Approaches

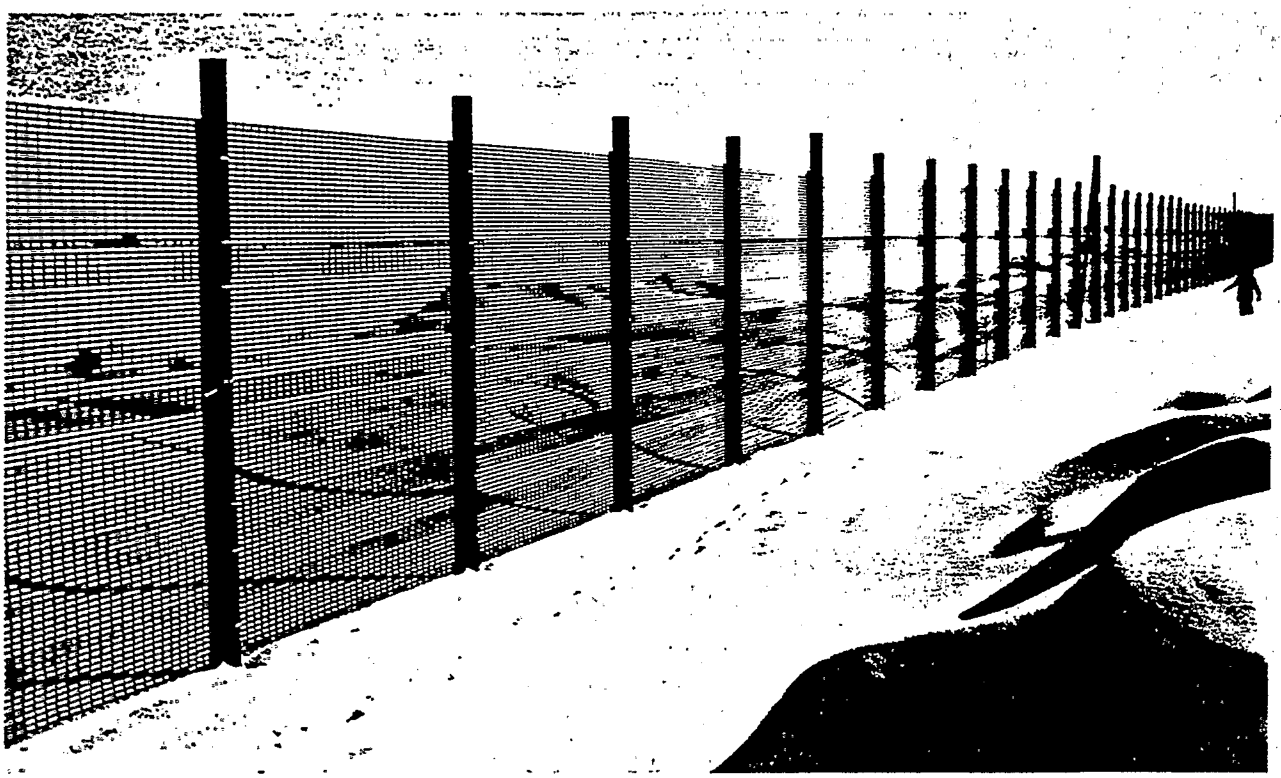
Many mechanical and design approaches have been and are being evaluated in an effort to improve snow and ice control practices. Some of these attempts have been very successful, while others have had limited success or need additional research. Pavement heating, pavement coatings, mobile thermal deicing equipment, snow fences, and snowplows are examined in this section. This is not an inclusive list of mechanical and design approaches to improve snow and ice control procedures.

Pavement heating and pavement coatings are two approaches to snow and ice removal that have had limited success due to cost or feasibility. Pavement heating systems are costly to install, and operational costs exceed salt on the order of 15 to 30 times (Lord, 1988). Mobile thermal deicing equipment has also been evaluated and determined to be impractical. Pavement coatings involve using hydrophobic or icephobic coatings to reduce the adhesion of ice and snow to the roadway. Pavement coatings are required to weaken or prevent bonding, while not decreasing traction in no snow conditions. They are also required to persist in extremely harsh conditions. Pavement coatings were generally unsuccessful because they were unable to meet these goals (Lord, 1988 and EPA, 1976). A 1976 EPA Manual, *Development of a Hydrophobic Substance to Mitigate Pavement Ice Adhesion* (EPA-600/2-76-242) describes this research.

Snow fences minimize costs associated with snow clearing, reduce the formation of compacted snow, and reduce the need for chemicals. Mechanical snow removal costs approximately 100 times more than trapping snow with fences (SHRP, 1991). However, the snow fence must be properly positioned and designed. A 4 foot picket fence in contact with the ground and improperly positioned was common 20 years ago (SHRP, 1991). Properly designed and positioned, taller fences are more effective than the traditional low picket fence. Lightweight plastics allow the construction of portable fences up to 8 feet tall (SHRP, 1991). A 15 foot tall snow fence used at Prudhoe Bay, Alaska is shown in Figure 1. To minimize improper positioning and design of snow fences, the SHRP provided publications such as *Design Guidelines for the Control of Blowing and Drifting Snow* (SHRP-H-381, 1994), *Snow Fence Guide* (SHRP-W/FR-91-106, 1991), and a 21 minute video entitled *"Effective Snow Fences"*.

Snowplow designs in the United States have evolved empirically, with scant regard to physical properties of the material being handled and with little consideration to aerodynamic and hydrodynamic principles involved in the flow of fluidizing snow. Consequently, the energy expended in displacing snow is disproportionate to the work performed, and the low cast distance requires unnecessary rehandling of the snow (Lord, 1988). The SHRP funded research at two universities to improve development of plow blade design and cutting edges for the plow blades (SHRP, 1991).

FIGURE 1. SNOW FENCE (15 FT TALL) LOCATED AT PRUDHOE BAY, ALASKA



Source: Design Guidelines for the Control of Blowing and Drifting Snow, SHRP-H-381, 1994

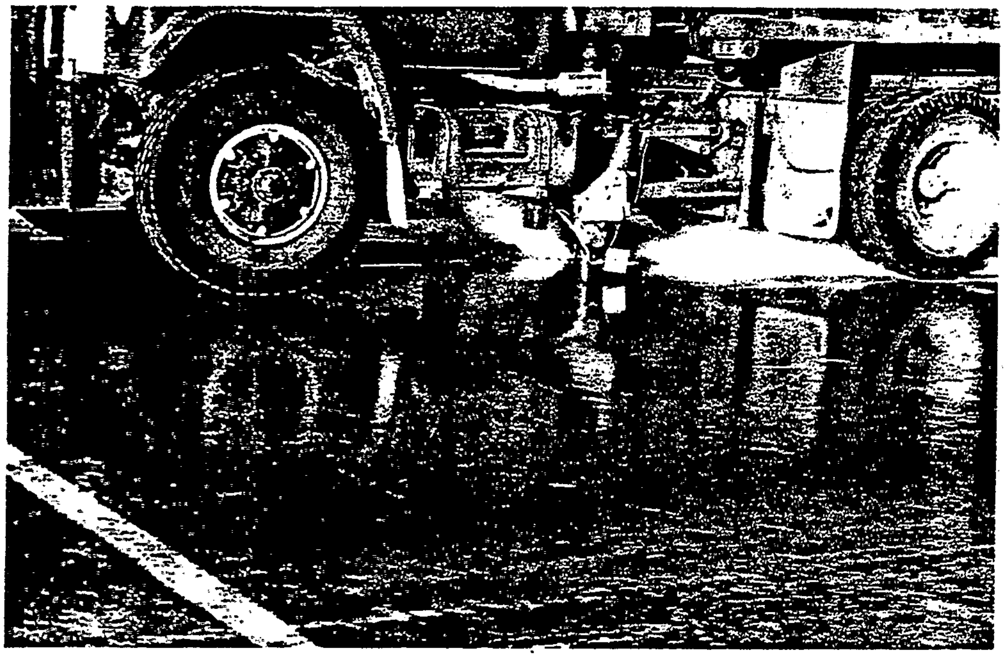
The first research project, conducted by the University of Wyoming Department of Mechanical Engineering, focused on developing an improved snowplow blade. The objective of this design was to produce a plow that minimizes energy needed to throw snow clear of the roadway. The plow design, based on analytical methods and laboratory scale experiments, showed a 20 percent improvement in efficiency over conventional plows. The plow underwent testing in West Yellowstone, Montana during the winter of 1990-1991 (SHRP, 1991). Research for additional technological advances in plow design is ongoing.

Another research project, conducted by the University of Iowa Institute of Hydraulic Research, evolved to improve snowplow efficiency by improving cutting edges of plow blades based on mechanics of ice cutting (SHRP, 1993). Laboratory tests were performed with a hydraulic ice cutting ram to determine the effects of the geometry on the cutting edge of a snow plow blade on the force required to remove ice from a highway pavement surface. Results of this research indicate that changes in the cutting edge geometry result in substantially improved ice cutting, although the cutting edge performance may benefit from further studies (SHRP, 1993). An Iowa Department of Transportation "plowing truck" is shown in Figure 2. Figure 3 shows a plowing truck which is cutting ice. Additional information can be obtained in the SHRP manual entitled, *Improved Cutting Edges for Ice Removal* (SHRP-H-346, 1993).

FIGURE 2. PLOWING TRUCK USED BY THE IOWA DEPARTMENT OF TRANSPORTATION

Source: Improved Cutting Edges for Ice Removal, SHRP-H-346, 1993

FIGURE 3. A PLOWING TRUCK CUTTING ICE



Source: Improved Cutting Edges for Ice Removal, SHRP-H-346, 1993

SUMMARY OF FINDINGS

The importance of snow and ice control in terms of public safety, environmental effects, and costs have prompted significant breakthroughs in technology. Technological breakthroughs and on-going research have increased and will continue to increase the effectiveness of snow and ice removal programs across the United States. However, these advances should be supplemented by additional research and testing in the future.

To date, one of the most important advances to these programs has been improving operational practices. These operational practices include guidelines on the following: planning, personnel training, equipment maintenance, spreader calibration, proper storage of deicing chemicals, proper maintenance around chemical storage areas, and an increased environmental awareness. Using proper storage facilities for deicing chemicals and proper application rates has significantly reduced improper and overuse of these chemicals. Best management practices for snow and ice removal should implement improved operational procedures supplemented by technological advances if they are feasible and cost effective.

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STORMWATER BMP: HANDLING AND DISPOSAL OF COLLECTED STORMWATER AND SEDIMENT CONTROL SOLIDS/RESIDUALS

OWM MTB
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INTRODUCTION

The total watershed has become increasingly important in defining modern urban stormwater management. Not long ago, stormwater management programs often provided little more than local storm drainage, with scant regard for downstream effects. Today, a broad range of "best management practices" (BMPs) have evolved because of increasing concern about comprehensive watershed protection. These practices are intended to protect aquatic and terrestrial habitat, wetlands and cultural resources by preventing or controlling erosion, sedimentation, and pollution runoff.

As technology has evolved to afford better environmental protection, operations and maintenance requirements have increased. Many modern stormwater BMPs are designed to capture and retain solids. The continued effectiveness of such BMPs depends on periodic inspection and removal of these "residuals".

This fact sheet summarizes the nature of the residuals problem, discusses the regulatory framework and presents the management options available, along with typical unit costs and practical considerations. In addition to the available literature, the following draws on the experience of a number of practitioners at both the state and local levels.

POLLUTION FROM URBAN RUNOFF

Urban runoff carries a wide variety of pollutants from many sources and activities. Oil and salt on roads, automobiles, atmospheric deposition, chemicals used in homes and offices, erosion from construction sites, industrial plants, pet wastes, wastes from processing and salvage facilities, and chemical spills are all typical sources of pollutant runoff. The quality of runoff water tends to worsen as urbanization increases. This is caused by an increase in the density of sources and a decrease in natural systems for capturing pollutants. Urbanization reduces the coverage of trees and other vegetation which once intercepted rainfall. Natural paths, such as stream banks, become channels. The erosive conditions increase the amount of sediment carried by runoff. Natural dips or depressions that had formed temporary ponds for rainwater storage may be lost by grading and filling for development. As asphalt and concrete replace vegetation, the quantity of runoff increases and it reaches surface water faster. When the land loses its ability to absorb and store rainwater, the groundwater table drops and stream flows decrease during dry weather.

Urban runoff can affect water quality in various ways depending on the type of pollutant in the runoff, the quantity and concentration of the pollutant, and the nature of the receiving waters. Some of the major pollutants include sediment (organic and inorganic), nutrients, bacteria, oil and grease, and heavy metals. Other activities, parameters, and pollutants which may affect water quality include the disturbance of stream habitats due to construction and erosion; impervious surfaces, temperature, toxic substances, chlorides, and trash/debris. Urban runoff can also cause loss of property and vegetation through erosion.

URBAN BEST MANAGEMENT PRACTICES

BMPs are an integral part of an urban stormwater management program. For new development, BMPs intended for an erosion and sediment control plan during the site development stage can be designed with long-term runoff management as part of the objective. Some BMPs are designed for long-term control; others are retrofit projects intended to correct problems resulting from the lack of stormwater management. Goals of a BMP are to reduce the erosive effects of runoff and minimize the pollutants in urban runoff, including toxic pollutants which may effect downstream waters. Selection of the proper BMPs or combination of BMPs is critical to achieve this goal. BMP selection criteria include: the site's physical condition and development; runoff control benefits provided by each BMP option; the pollutant removal capability of each BMP option under several design scenarios; the environmental and human health advantages of each BMP option; the ultimate use of the receiving water body; and the long-term maintenance cost of the BMP.

Urban BMPs can generally be grouped in the following categories: detention basins, retention/infiltration devices, vegetative controls, and pollution prevention. Detention basins are widely used and are very effective in reducing suspended solid particles by temporarily holding the stormwater runoff and allowing the sediments to settle. Dry ponds, wet ponds, and extended detention dry ponds are examples of detention basins. Detention basins can reduce suspended solids concentrations by 50 to 95 percent. In addition, since detention basins delay the amount of runoff released into receiving waters, downstream flooding and streambank erosion from high flows are reduced and stress on the physical habitat is lessened.

Infiltration devices allow runoff to percolate into the ground, thereby reducing the amount of pollutants released into the receiving water. Infiltration basins, infiltration trenches and dry wells, and porous pavement are some examples of infiltration devices. The filtration and adsorption mechanism traps many pollutants (e.g., suspended solids, bacteria, heavy metals, and phosphorus) in the upper soil layers and prevents them from reaching groundwater. Infiltration devices can remove up to 99 percent of some runoff pollutants, depending on the percolation rate and area, soil type, pollutants present, and available storage volume. Retention devices are also used as pretreatment devices to treat runoff before it enters the stormwater collection system or infiltrates into the ground. Sand filters and oil/grit separators are examples of these devices. There has been limited success with some of these devices. Negative aspects of oil/grit separators are their limited ability to remove pollutants caused by low average detention times, and the resuspension and release of settled material during later storms.

Vegetative BMPs are used to decrease the velocity of stormwater runoff. This promotes infiltration and settling of suspended solids and also prevents erosion. Basin landscaping, filter strips, grassed swales, and riparian reforestation are examples of vegetative BMPs. Vegetative BMPs also remove organic material, nutrients, and trace metals. For maximum effectiveness, vegetative controls should be used as a first line of defense in removing pollutants in combination with other BMPs.

Pollution prevention is a source reduction program usually classified as a non-structural BMP. Local governments and industries establish pollution prevention programs to reduce the generation and exposure of pollutants that accumulate on streets, parking lots, and other surfaces, and eventually wash into streams and lakes. Examples of pollution prevention controls include land use planning, zoning strategies, street sweeping, good housekeeping practices, public education/awareness, and community involvement. A combination of a pollution prevention program and a structural urban BMP within the framework of a watershed management plan is usually required.

OPERATION AND MAINTENANCE OF URBAN BMPS

Proper operation and maintenance (O&M) procedures for all structural BMPs are essential to ensure their continued effectiveness. These O&M procedures may include the following: periodic inspections; pipe, pump, and structure maintenance; erosion control; nuisance control; general housekeeping; and debris and sediment removal. Periodic inspections are important to ensure that the structure operates in the manner originally intended. Inspections of municipal BMPs are usually performed by the local jurisdiction under state inspection criteria. Ideally, these inspections occur annually during wet weather to assess the BMP's effectiveness.

Erosion control may be necessary for some types of BMPs. Corrective measures such as regrading and revegetation may be necessary. Nuisance control is probably the most frequent maintenance item demanded by the local residents. Control of insects, weeds, odors, and algae may be needed with some BMPs. Some general housekeeping maintenance practices include grass cutting, vegetation control, and litter/debris removal.

For the BMP to achieve maximum pollutant removal it is necessary to periodically remove the stormwater residuals and sediment solids from the system. The removal of collected stormwater and sediment control solids/residuals is very site specific. However, it is possible to provide a general discussion for each structural BMP category (i.e., detention basins, retention/infiltration devices, and vegetative controls). O&M procedures for removing and handling stormwater solids/residuals from BMPs should be planned in the design stages of the BMP.

Detention Basins

Wet ponds will eventually accumulate enough sediment to significantly reduce storage capacity of the permanent pool. This loss of capacity can reduce both the appearance and the pollutant removal efficiency of the pond. The best available estimate is that approximately one percent of the storage volume capacity associated with the two year design storm can be lost annually (MWCOG, 1987). Even more storage capacity can be lost if the pond receives large sediment input during the construction phase. A sediment clean-out cycle of 10 to 20 years is frequently recommended in the Washington, D.C. metropolitan area (APWA, 1981; MWCOG, 1983b). According to the Center for Watershed Protection, stormwater ponds should require sediment clean-out on a 15 to 25 year cycle (Schueler and Yousef, 1994). Most ponds are now designed with a forebay to capture the majority of sediments decreasing the solids load to the wet pond. A common forebay sizing criterion is that it should constitute at least 10 percent of the total pool volume (Schueler and Yousef, 1994). This forebay could lose 25 percent of its capacity within 5 to 7 years based on a 0.5 inch/year muck deposition rate and the assumption that a forebay traps 50 percent of all muck deposited in the pond (Schueler and Yousef, 1994). However, using a forebay, the sediment removal frequency for the main pond may be extended to 50 years (Schueler and Yousef, 1994).

To clean out a larger wet pond, dragline or hydraulic dredge methods may be necessary. Dipper, clamshell, or bucket dredges are mechanical dredge methods, which are sometimes used on ponds which are not large enough to warrant a hydraulic dredge method. With smaller wet ponds, the pond level may be drawn down to a point where the residuals can begin to dry in place. After the material is dried, a front end loader can be used to remove it from the pond bottom.

Dry ponds and extended detention dry ponds also accumulate significant quantities of sediments over time. This sediment gradually reduces available stormwater management storage capacity within the pond and also reduces pollutant removal efficiency. Sediment accumulation can make dry ponds unsightly. In addition, sediment may tend to accumulate around the control device of the dry extended detention ponds. This sediment deposition increases the risk that either the orifice or the filter medium will become clogged, and also gradually reduces storage capacity reserved for pollutant removal in the lower stage. Therefore, in an extended detention dry pond it is recommended that sediment be removed from the lower stage every 5 to 10 years (MWCOG, 1987). Sediment removal from these systems is relatively simple if access is available for the equipment. Therefore, it is essential that access be included in the pond design. Front-end loaders or backhoes can be used to remove the accumulated sediment.

Retention/Infiltration Devices

Infiltration basins are usually located in smaller residential watersheds that do not generate large sediment loads or are equipped with some kind of sediment trap. Even when the sediment loads are low, they still have a negative impact on the basin's performance. The sediment deposits reduce the storage capacity reserved for exfiltration and may also clog the surface soils. Methods to remove sediment are different from those utilized for detention basins. Removal should not begin until the basin has thoroughly dried out, preferably to the point where the top layer begins to crack. The top layer should then be removed using lightweight equipment, being careful not to unduly compact the basin surface. The remaining soil can then be deeply tilled with a rotary tiller or disc harrow to restore infiltration capacity. Vegetated areas disturbed during sediment removal should be revegetated immediately to prevent erosion.

Infiltration trenches require that the pretreatment inlets of underground trenches be checked periodically and cleaned out when sediment depletes more than 10 percent of the available trench capacity. This can be done using a vacuum pump or manually. Inlet and outlet pipes should also be checked for clogging and vandalism. Dry wells should also be checked periodically for clogging. Performance of sand filter systems may be sustained through frequent inspections and replacement of the filter media every 3 to 5 years depending on the pollutant load. Accumulated trash and debris should be removed from the sand filters every 6 months or as necessary. Sand filter systems are usually cleaned manually (Parsons ES, 1995). Sediment is removed from porous pavement using vacuum sweeping. It has been recommended that the porous pavement be vacuum swept four times per year, followed by high-pressure jet hosing, to keep the pores open in the asphalt (MWCOG, 1987).

Ideally, oil/grit separators should be cleaned out after every storm event to prevent re-entry of any residuals or pollutants into the storm sewer system during the next storm event. However, due to the O&M costs and manpower requirements associated with this cleaning schedule, less frequent cleaning usually occurs at a point when an oil/grit separator is no longer operating effectively. The Metropolitan Washington Council of Governments recommends that oil/grit separators be cleaned out at least twice a year (MWCOG, 1987). As with all BMPs, the cleaning frequency depends upon the pollutant load which is site specific. Oil/grit separators can be cleaned out using several methods. One method to clean an oil/grit separator is to pump out the contents of each chamber. The turbulence of the vacuum pump in the chamber produces a slurry of water and sediment that can then be transferred to a tanker truck. The other method involves carefully siphoning or pumping out the liquid from each chamber (without creating a slurry). If needed, chemicals can then be added to help solidify the residuals. The solidified solids/residuals can then be removed manually from the separator.

Vegetative Controls

Vegetative controls (basin landscaping, filter strips, grassed swales, and riparian reforestation) rely on various forms of vegetation to enhance pollutant removal, habitat value, or appearance of a development site. These controls should be used in combination with other BMPs. Some natural systems require periodic sediment removal. For example, accumulated sediments deposited near the top of a filter strip will periodically need to be removed manually to keep the original grade.

PROPERTIES OF STORMWATER SOLIDS/RESIDUALS

Stormwater solids/residuals have properties that are very site specific. It is difficult to precisely estimate "typical" stormwater or sediment residual properties by the BMP employed or even by site classification such as residential, commercial, or industrial. A recent study by Schueler and Yousef reviewed bottom sediment chemistry data from 37 wet ponds, 11 detention basins, and two wetland systems, as reported from 14 different researchers. This research covered a broad range of geography, although nearly 50 percent of the sites were located in Florida or the Mid-Atlantic states. These stormwater ponds had been in use from 3 to 25 years. Sampling and analysis was restricted to mean dry weight concentrations of the surface sediments that comprise the muck layer, which is usually the top 5 centimeters (Schueler and Yousef, 1994). Properties of stormwater solids/residuals presented in this 1994 study and in three other technical papers, discussed in the next paragraph, are presented in the following sections. A summary of this data is presented in Table 1.

A 1982 study performed at Marquette University, Milwaukee, Wisconsin, obtained urban runoff residuals from a field-assembled sedimentation basin in Racine, Wisconsin, swirl and helical bend solids separators in Boston, Massachusetts, and an in-line upsized storm conduit in Lansing, Michigan. The residual samples from Racine and Boston were obtained from individual storm events, while the Lansing samples represent a six month accumulation of residuals. All of the sample locations were primarily residential (EPA - Marquette University, 1982). Results from the sampling are shown in Table 1. Also shown in Table 1 are the findings documented in two other technical papers (EPA - Rexnord, Inc., 1982, and Field and O'Shea, 1992).

In a 1994 paper on Pond Muck (pond sediment), Schueler and Yousef indicate that the properties of the solids/residuals from all BMPs are similar except for oil/grit separators. Analyzed properties mentioned in the paper include the following: nutrients, trace metals (cadmium, copper, lead, zinc, nickel, chromium), hydrocarbons, and priority pollutants. A noted exception, was that grassed swale soils tend to have about twice as much phosphorus and lead as detention ponds. Only one sand filter had been sampled, but these characteristics appeared similar to other BMPs (Schueler and Yousef, 1994). Characteristics of solids/residuals from BMPs are discussed in the following sections, with the exception of oil/grit separators which warrant a separate subsection.

Solids

Solids from stormwater and sediment BMPs can consist of organic and inorganic material. According to Schueler and Yousef (1994), the muck layer of a pond has a high organic matter content. An average of nearly 6 percent volatile suspended solids was reported. Pond muck solids have a very soupy texture with an average total solids content of 43 percent, although this parameter was reported from only 15 out of the 50 site locations. It was also described as having a distinctive grey to black color. These residuals have a low density averaging approximately 1.3 g/cm3. These solids/residuals also consist of poorly-sorted sands and silts dominating the muck layer (Schueler and Yousef, 1994).

According to a 1982 EPA study at Marquette University, total solids concentration of residuals samples from a sedimentation basin in Racine, Wisconsin ranged from 233 to 793 mg/l, with 104 to 155 mg/l being volatile. Urban runoff residual samples from swirl and helical bend solids separators in Boston, Massachusetts ranged from a total solids concentration of 344 to 1,140 mg/l, with 107 to 310 mg/l being volatile. The six month accumulated samples from the in-line upsized storm conduit in Lansing, Michigan had a total solids concentration of 161,000 mg/l with 25,800 mg/l being volatile (EPA - Marquette University, 1982). A 1992 paper by Field and O'Shea reported estimated annual residual/sludge volumes for urban storm runoff in the United States ranging from 27 to 547 million cubic meters (35 to 715 million cubic yards) at an average total solids content ranging from 0.5 to 12 percent (Field and O'Shea, 1992).

TABLE 1
PROPERTIES OF URBAN STORMWATER SOLIDS/RESIDUALS

Properties of Residuals	Wet Ponds[1]	Sedimentation Basin[2]	Swirl and Helical Bend Solids Separators[3]	In-Line Upsized Storm Conduit[4]	Urban Stormwater Runoff Residuals[5]
<u>Solids</u>					
VSS	6%	104-155 mg/l	107-310 mg/l	25,800 mg/l	90 mg/l
TSS	43%	233-793 mg/l	344-1,140 mg/l	161,000 mg/l	415 mg/l
<u>Nutrients</u>					
Phosphorus	583 mg/kg	< 5 mg/l	< 5 mg/l	0.3-2,250 mg/l	502 - 1,270 mg/kg
TKN	2,931 mg/kg	< 5 mg/l	< 5 mg/l	0.3-2,250 mg/l	1,140 - 3,370 mg/kg
<u>Heavy Metals</u>					
Zinc	6 - 3,171 mg/kg	-	-	-	302 - 352 mg/kg
Lead	11 - 748 mg/kg	-	-	-	251 - 294 mg/kg
Chromium	4.8 - 120 mg/kg	-	-	-	168 - 458 mg/kg
Nickel	3 - 52 mg/kg	-	-	-	69 - 143 mg/kg
Copper	2 - 173 mg/kg	-	-	-	251 - 294 mg/kg
Cadmium	ND - 15 mg/kg	-	-	-	-
Iron	-	6.1 - 2,970 mg/l	6.1 - 2,970 mg/l	6.1 - 2,970 mg/l	-
Hydrocarbons	2,087 - 12,892 mg/kg	-	-	-	-
PCBs	-	0.19 - 24.6 μg/l	-	0.19 - 24.6 μg/l	-

[1]Schueler and Yousef, 1994
[2]EPA - Marquette University, 1982 (Racine, Wisconsin)
[3]EPA - Marquette University, 1982 (Boston, Massachusetts)
[4]EPA - Marquette University, 1982 (Lansing, Michigan)
[5]Field and O'Shea, 1992

Nutrients

The muck layer is enriched with nutrients. In the 1994 paper by Schueler and Yousef, phosphorus concentrations were reported for 23 studies. The phosphorus concentrations ranged from 110 to 1,936 mg/kg, with an average concentration of 583 mg/kg. Nearly all of the nitrogen found in pond muck is organic in nature. Total kjeldahl nitrogen (TKN) concentrations were reported for 20 studies and ranged from 219 to 11,200 mg/kg, with an average concentration of 2,931 mg/kg. Nitrate was found to be present in very small quantities. This either indicates that some denitrification is occurring in the sediments or perhaps that less nitrate is initially trapped in the muck layer. The nitrogen to phosphorus ratio in this pond study averages 5 to 1. In comparison, the nitrogen to phosphorus ratio for incoming stormwater usually averages about 7 to 1. Ponds appear to be more effective in trapping phosphorus than nitrogen. Another explanation for the lower ratio is that the decay rate for nitrogen in the muck layer is thought to be more rapid than for phosphorus (Schueler and Yousef, 1994).

A 1982 EPA report and a 1992 paper by Field and O'Shea reported urban sludge nutrient concentrations ranging from 502 to 1,270 mg/kg total phosphorus as P and 1,140 to 3,370 mg/kg TKN. These nutrient concentrations were reported as being lower than nutrients found in combined sewer overflows (CSOs) and raw primary sludges (EPA - Rexnord, Inc., 1982 and Field and O'Shea, 1992). Another 1982 EPA report presented the concentration of individual nutrients [total phosphorus, TKN, ammonia-nitrogen (NH_3), nitrite-nitrogen (NO_2), and nitrate-nitrogen (NO_3)] in stormwater sediment samples from Boston, Massachusetts and Racine, Wisconsin as never exceeding 5 mg/l. Urban stormwater sediment samples taken from Lansing, Michigan were between 0.3 and 2,250 mg/l for individual nutrients (total phosphorus, TKN, NH_3, NO_2, and NO_3) (EPA - Marquette University, 1982).

Heavy Metals

According to the Northern Virginia Planning District Commission (NVPDC), sediment toxicity has been measured and analyzed in the Northern Virginia area (Guliea, 1995). One of these studies by Dewberry and Davis, 1990, is entitiled "Investigation of Potential Sediment Toxicity From BMP Ponds". This report analyzed sediments from 21 ponds in Northern Virginia under various land use conditions. Many of these ponds are owned and maintained by a property owner or a homeowners' association. Testing was performed for the presence of metals and to determine if the metals concentration is classified as toxic. The Extraction Procedure (EP) toxicity test was used by Dewberry and Davis in the analysis. Conclusions of this report indicate that the stormwater sediments tested were not hazardous and could be safely disposed of on-site or in a landfill. Sediments should be tested further for there use as backfill material or topsoil maintenance (Dewberry and Davis, 1990).

NVPDC had noted that while the 1990 study by Dewberry and Davis determined the material to be non-hazardous, characteristics of stormwater sediments are very site specific. In every jurisdiction in Northern Virginia, it is the responsibility of the owner/operator of the BMP to maintain and operate the system. However, this may vary from state to state. In addition, it is also recommended to plan and design a BMP for on-site disposal of the material (Guilea, 1995).

Trace metal levels are typically 5 to 30 times higher in the muck layer of a pond than in the parent soil below the muck layer (Schueler and Yousef, 1994). Trace metal levels were also reported to follow a relatively consistent pattern and distribution. The zinc concentration in the muck layer was the highest followed by lead. Zinc and lead concentrations were much greater than chromium, nickel, and copper concentrations which were approximately equal. Cadmium had the lowest concentration in the muck layer. In the 1994 Schueler and Yousef study, 50 ponds and wetlands were examined and found to have zinc concentrations ranging from 6 to 3,171 mg/kg (dry weight). Lead and chromium concentrations ranged from 11 to 748 mg/kg, and from 4.8 to 120 mg/kg, respectively. Nickel and copper concentrations ranged from 3 to 52 mg/kg, and from 2 to 173 mg/kg, respectively. Cadmium concentrations ranged from being non-detectable to 15 mg/kg (Schueler and Yousef, 1994).

Field and O'Shea indicate that median concentrations of zinc, lead, copper, nickel, and chromium in urban runoff sludges and residuals were reported as 316, 268, 263, 131, and 189 mg/kg, respectively (Field and O'Shea, 1992). In the 1982 study at Marquette University, iron was found as the highest concentration of metals in all of the samples ranging in concentration from 6.1 to 2,970 mg/l. Lead and zinc concentrations ranked second and third, respectively (EPA - Marquette University, 1982).

As with all pond parameters, trace metal concentrations are site specific. Ponds that primarily service roadways and highways are enriched with trace metals which are presumably associated with automotive loading sources (e.g., cadmium, copper, lead, nickel, and chromium). On the other hand, stormwater ponds that service primarily residential areas have the lowest trace metal concentrations (Schueler and Yousef, 1994). In general, the muck layer is highly enriched with metals; however, in most cases it should not be considered an especially toxic or hazardous material. For example, none of over 400 muck layer samples from any of the 50 pond sites examined in the referenced 1994 study exceeded EPA's current land application criteria for metals (Schueler and Yousef, 1994).

Hydrocarbons

There is limited data on hydrocarbon and poly-aromatic hydrocarbon (PAH) concentration in the muck layer of ponds. It was reported that the concentration of total PAH and aliphatic hydrocarbons in the muck layer of a 120 year old London basin were 3 to 10 times greater, respectively, than the base "parent" sediments. Minor degradation of the hydrocarbons trapped in the muck layer appeared to have occurred in the basin in recent years. On the other hand, hydrocarbons were rarely detected in the muck of Florida ponds. Hydrocarbon concentrations were reported for 2 out of the 50 sites in the 1994 report by Schueler and Yousef. These concentrations were reported for a industrial and residential site as 12,892 and 2,087 mg/kg, respectively (Schueler and Yousef, 1994).

Bacteria

Urban stormwater solids may contain high levels of bacteria and viral strains, including fecal streptococcus and fecal coliform from animal and human wastes. These bacteria have the potential to be spread from land application of stormwater residuals or landfill sites unless the proper precautions are taken. Measures which reduce their concentration in the sludge and minimize any sludge-vector contact include the following: stabilization of the solids; immediate covering of landfill trenches after disposal of these solids; the treatment of these bacteria in the solids by pasteurization, heat treatment, irradiation, etc; and public and animal access control away from the site (Field and O'Shea, 1992).

Other Pollutants

Other pollutants which may be toxic include pesticides and polychlorinated biphenyls (PCBs). Toxic wastes may also be present in fertilizers, herbicides, and household substances such as paints and cleaning materials. All of these pollutants may find their way into stormwater solids/residuals. In the 1982 report from Marquette University, PCBs were observed in measurable concentrations in the Racine, Wisconsin and the Lansing, Michigan samples. These concentrations ranged from 0.19 to 24.6 μg/l. Of eight pesticides surveyed only three (DDT, DDD, and Dieldrin) were observed in measurable concentrations (EPA - Marquette University, 1982).

Oil/Grit Separators

As previously mentioned, the stormwater and sediment solids collected by an oil/grit separator contain unique characteristics compared to other stormwater BMPs. The metal content of trapped sediments in an oil/grit separator may be 5 to 20 times higher than in other BMPs, especially if this separator services a gas station. Priority pollutant and hydrocarbon levels are also much higher. These higher levels reflect the fact that most oil/grit separators service areas that may discharge higher pollutant levels such as at gas stations or industrial sites, and are designed to trap lighter fractions of oil which may not be trapped by other BMPs. Other BMPs, such as detention basins, usually drain larger watersheds that dilute the influence of higher hydrocarbon or metal concentrations like those seen from gas stations or industries. Therefore, it is doubtful if solids from other BMPs would approach metal and hydrocarbon concentrations as high as those recorded with oil/grit separators (Schueler and Yousef, 1994).

STORMWATER SOLIDS/SLUDGE HANDLING ALTERNATIVES

Centralized Treatment (Bleed/Pump Back To The Dry Weather Treatment Plant)

Centralized treatment involves temporary storage of stormwater solids followed by its regulated release into a sanitary sewer during dry weather flow conditions. Advantages of this residuals handling alternative include the possible achievement of flow equalization through the timed addition of urban storm runoff to the dry weather influent, and the use of a central, pre-existing treatment facility and transportation system. Disadvantages of this system include: the deposition of large amounts of grit in the sewer system; the potential for exceeding the capacity of the dry weather treatment facility; any impacts to the treatment plant operation and efficiency which may arise due to differences in the characteristics of sanitary wastewater and urban storm runoff residuals; and additional cost for treatment (Field and O'Shea, 1992). The problems associated with bleed/pump back solids stormwater/sediment solids are similar to those evaluated with regard to CSO sludges.

Huibregste determined that "Centralized Treatment" was generally not practical (Huibregtse et al, 1977). In addition to the disadvantages already listed, some problems which may be associated with this type of system include: difficulties in effectively equalizing flow to the dry weather treatment plant due to the high solids/low volume characteristic of sludges; and difficulties maintaining sludge quality. Significant increases in heavy solids and toxic substance loadings will have an impact on treatment plant operation and effluent quality. The addition of large amounts of gritty solids can grossly overload solids handling facilities at treatment plants, and have a negative impact on overall sludge quality. Moreover, the addition of these stormwater and sediment residuals to the treatment system will increase the quantity of sludge which must be handled (Field and O'Shea, 1992). In a 1982 EPA report, research indicated that the number of days required for bleed/pump back of the residuals without overloading the dry weather treatment facility ranged from 2.8 to 3.9. This was considered an unacceptable bleed/pump back period, considering the likelihood of overlapping rainfall events (Huibregste et al, 1977).

Stormwater Solids Handling at Satellite Treatment Facilities

Another handling alternative for urban stormwater and sediment solids is treatment at a satellite facility. Average characteristics of urban storm runoff differ substantially from those of sanitary wastewater. For the treatment of stormwater runoff, biological processes are generally not employed due to its low organic and nutrient content as well as the intermittent and varying quantity and quality of the storm flow. The major differences affecting treatment process design include urban runoff's high grit content, low organic content, intermittent nature, and short flow duration (Field and O'Shea, 1992).

Evaluation of several CSO sludge handling processes by Huibregste found the most effective unit processes to be: conditioning through chemical treatment; gravity thickening; stabilization through lime addition; dewatering through vacuum or pressure filtration; and disposal through land application or landfill (Huibregste et al, 1977). In a 1982 report by Huibregste a cost analysis was performed specifically for the handling and disposal of urban storm runoff residuals. This cost analysis compared the following six alternative sludge handling scenarios for either swirl or sedimentation concentrated solids: (1) gravity thickening, vacuum filtration and landfill; (2) gravity thickening, vacuum filtration and landspreading; (3) gravity thickening, pressure filtration and landfill; (4) gravity thickening, pressure filtration and landspreading; (5) gravity thickening and landspreading; or, (6) landspreading. These cost estimates by Huibregste et al, 1982, are presented in terms of dollars per acre for residuals handling in an urban storm runoff area of 15,000 acres. These estimates were updated to July 1995 dollars and are presented in Table 2. As shown on Table 2, the most cost effective solids handling scenario based on annual costs is lime stabilization, gravity thickening, pressure filtration, and landfilling.

A 1982 EPA report from Marquette University concluded that of those options evaluated the most cost-effective means for handling and disposal of urban stormwater runoff residuals is gravity thickening followed by lime stabilization and landspreading or landfilling (EPA - Marquette University, 1982). This conclusion was based on urban stormwater studies from Boston, Massachusetts, Racine, Wisconsin, and Lansing, Michigan involving solids sampling, characterization, analysis, and treatability. The characterization study included analyses for nine metals, eight pesticides and PCBs, solids, nutrients, and organics. The treatability study included bench scale sedimentation tests, centrifugation tests, lime stabilization tests and capillary suction time tests (EPA - Marquette University, 1982). Other bench scale studies were performed by Carr in 1982 that evaluated the effectiveness of three dewatering alternatives for stormwater runoff residuals from sedimentation basins and swirl concentrators. These dewatering alternatives were gravity thickening, centrifugation, and capillary suction. Data from these studies indicated that the most effective method for concentrating urban stormwater runoff residuals was gravity thickening (Carr et al, 1982).

These bench scale studies identified some effective treatment methods for urban stormwater runoff residuals. However, characteristics of urban stormwater residuals are very site specific. Testing and analysis may be necessary to determine what level of treatment is necessary to dispose of these residuals.

On-Site Handling of Stormwater Solids/Sludge

The third alternative for handling/disposal of stormwater runoff residuals is on-site handling. This option may be used after the residuals have been analyzed and determined to be a non-hazardous material. During the design stage of a BMP, a dedicated area on the site should be set aside for land application or land disposal of the residuals. The area for this material should be carefully selected to prevent residuals from flowing back into the BMP during rainfall. On-site handling of this material is usually very cost effective as it avoids transportation costs and landfill tipping fees.

The stormwater runoff residuals must first be removed from the BMP. Alternatives for removing solids from various BMPs were discussed previously. After the solids are removed from the BMP, they will usually require dewatering. Dewatering is accomplished by spreading the material out on the ground and occasionally turning it. A front-end loader can be used for this. This material is then either land applied or land disposed. Land application involves spreading the material to the land at approved application rates. This material cannot be applied to a direct food chain crop and would probably be applied to a meadow or vegetated area. There is very little nutrient value associated with stormwater residuals. Land disposal consists of piling the material on an approved location at the site.

In some cases it may not be feasible to land apply or land dispose of the material on-site. This may be due to limited space on-site initially or limited space due to the accumulation of material. In any case, after the material is removed from the BMP it should be dewatered on-site if this is feasible. This will cut down on the volume of material to be transported. The material can then be loaded using a front-end loader and transported to either a landfill or another site for land application or land disposal.

TABLE 2

COST ESTIMATE ($/acre) FOR RESIDUALS HANDLING IN AN URBAN STORMWATER RUNOFF AREA OF 15,000 ACRES (1)

Sludge Handling	Sedimentation			Swirl Concentration		
Method	Capital	O&M	Annual	Capital	O&M	Annual
Lime Stabilization Gravity Thickening Vacuum Filtration Landfill	475	71	134	507	64	130
Lime Stabilization Gravity Thickening Vacuum Filtration Landspreading	507	76	171	531	67	155
Lime Stabilization Gravity Thickening Pressure Filtration Landfill	492	60	124	550	49	117
Lime Stabilization Gravity Thickening Pressure Filtration Landspreading	522	64	156	569	50	139
Lime Stabilization Gravity Thickening Landspreading	---	---	---	394	87	166
Lime Stabilization Landspreading	308	104	186	1025	856	1194

Note: (1) Huibregste et al, 1982. Costs have been updated to July 1995 dollars using the ENR.

REGULATIONS (CURRENT AND PENDING) AND LIABILITIES

Traditional point sources of water pollution are regulated by the EPA and individual states under the National Pollutant Discharge Elimination System (NPDES) permit program. This program was established by section 402 of the Clean Water Act, and establishes permit requirements for certain municipal and industrial stormwater discharges. However, the regulations governing the handling and disposal of stormwater runoff residuals is not as well defined.

Most states have regulations for runoff quality control. To adhere to these regulations, many local governments have implemented drainage and flood control regulations. Some local governments have also adopted localized stormwater quality and erosion/sediment control regulations which require BMPs. To help local governments implement and properly operate these BMPs, states issue guidance documents for local jurisdictions which are responsible for inspecting, maintaining, and ensuring proper operation of stormwater BMPs. Some states will also periodically inspect a local jurisdiction's stormwater management program.

In reality, many local jurisdictions do not have the manpower to inspect all BMPs regularly. BMPs which are not maintained do not perform efficiently. If not maintained, pollutants removed by the BMPs can be released back into the stormwater. An oil/grit separator is a good example of this. Some BMPs, such as detention basins, were installed by local jurisdictions in the 1980s and are now requiring or have not yet required cleaning/dredging for the first time. This is a learning experience for many jurisdictions that have not yet had to (or are doing it for the first time) dredge this material or handle/dispose of it.

Stormwater and sediment solids/residuals should initially be tested prior to disposal. If they are not hazardous, they will usually require dewatering prior to disposal. Some disposal methods for this material can be landfilling, land application, land disposal, and even incineration (e.g, non-hazardous solids from oil/grit separators). Historically, and in most cases, the disposal of sediments removed from BMPs has posed no special regulatory or legal difficulty. Many municipalities and industries have disposed of such sediments in the same way that they would have any uncontaminated soil (Jones et al, 1994). In fact, after drying, stormwater sediment has been mixed with other soil and reused as backfill on construction projects (Jones et al, 1994) as well as cover for landfills (Cox, 1995).

If the residuals/solids from a BMP are determined to be hazardous, they must be managed according to the Resource Conservation and Recovery Act of 1976 (RCRA) requirements. Wastes can be defined by RCRA as hazardous because they either have certain characteristics or contain constituents specifically listed in the RCRA regulations. Certain characteristics include ignitability, corrositivity, explositivity, or toxicity. In nearly all cases involving stormwater BMP solids, sediments could be classified as a hazardous waste because they contained listed chemicals rather than because the sediments are hazardous by characteristic (Jones et al, 1994). Simply because a chemical regulated by RCRA is detected in BMP sediments, does not render the sediment a hazardous waste. If no sample containing greater than ten percent of the listed chemical (by volume), or if contact with precipitation/runoff is unlikely, the sediment would not be classified as hazardous (Jones et al, 1994). Hazardous waste material must be disposed or handled according to RCRA regulations which would either require treatment to lessen the concentration of the hazardous constituent or disposal in a hazardous waste landfill.

EXAMPLES/CASE STUDIES

The following BMP residual management programs have been implemented by several municipalities, states, and a company which cleans oil/grit separators for various clients. This section is not inclusive, but is presented to illustrate how some states, municipalities, and industries manage the solids/sediments from BMPs.

Waste Reduction, Disposal, and Recycling Services

A Baltimore, Maryland firm cleans oil/grit separators for many commercial areas and industries. They use a three man crew and two trucks to clean these BMPs. A liquid tanker truck is used to pump the oil and water out of the separator. This mixture is transported to their facility in Baltimore for treatment (Schorr, 1995).

The solids in the oil/grit separator are further solidified using chemical addition. Once the material is solidified, it is shoveled out of the separator into 55 gallon drums. A composite sample is taken from each drum. This material is analyzed for toxicity, ignitibility (flash test), and PCBs. If the material is determined to be non-hazardous, the drums are taken back to their Baltimore facility. The material is then loaded into roll-off dumpsters and transported to an incinerator where they receive a certificate of destruction for the material (Schorr, 1995).

As each cleaning and maintenance job is site specific, this firm charges by the hour. The cost for cleaning is $202/hr for the three employees and two trucks. In addition, disposal of the liquid waste is $0.35/gallon, charge for the chemical that aids in solidification is $9.95/bag, drum purchase cost is $25/drum, drum disposal cost is $100, analytical charge is $145, and transportation charge is $250. It was emphasized that these oil/grit separators should be cleaned periodically. Cleaning schedules of oil/grit separators are site specific. For example, a typical commercial building may be cleaned one time per year, whereas, an industry may have its oil/grit separators cleaned approximately every three months (Schorr, 1995).

If the material is determined to be hazardous, it is dealt with in an appropriate method depending on the hazardous constituent of the waste. A copy of the analytical results are faxed to the generator. Additional testing is usually required to determine what constituent(s) is present in the sediment to classify it as a hazardous material (Schorr, 1995).

A hazardous material is handled on a case-by-case basis. Additional analytical testing and handling of the hazardous material will increase costs. In most cases, treatment to lower the hazardous chemical concentration to a non-hazardous level is preferred over landfilling in a hazardous waste landfill. For example, a sediment that contained a high hydrocarbon content, which may occur at a service station, would be spread out on an approved site for a period of time sufficient to allow the concentration to decrease in the sediment (Schorr, 1995).

Prince George's County, Maryland

In Prince George's County, Maryland, BMPs such as wet ponds have been in service long enough that they are just beginning to require dredging. In some cases, on-site disposal of the sediment was planned for in the design of the BMP. However, if on-site disposal is not an alternative then locating a site for disposal of the material is a major operation. Residual sand and gravel material from the BMP is transported to construction-sites for use or is disposed of on-site (Coffman, 1995).

Oil/grit separators are being phased out in Prince George's County for the following reasons all of which pertain to residuals management: sometimes the landfill will not accept the material; they require frequent maintenance and cleaning; the material is difficult to dewater; and the material is expensive to dewater, haul, and landfill (when the landfill accepts the material). In addition, the county does not have the personnel to routinely inspect and enforce the cleaning of oil/grit separators. As an alternative to this BMP, the county is focusing on pollution prevention and is also evaluating bioretention (Coffman, 1995).

Fairfax County, Virginia

Fairfax County has very few wet ponds. The wet ponds in the county are large lakes which can properly function up to 100 years without dredging (Henry, 1995). The county has not dredged a wet pond since 1991. A small mini-dredge is used for dredging wet ponds. For the smaller ponds, the lake level is lowered and attempts are made to dry the sediment material. After this, a clamshell or bucket dredge is used to remove the material. Material is either disposed of on-site or in a landfill. Sediments from dry ponds are dried on-site and removed using a front-end loader. This material is either landfilled or disposed of on-site (Henry, 1995).

Montgomery County, Maryland

Montgomery County has wet ponds and dry ponds, the majority of which have not required dredging. The State of Maryland has determined that the sediment from these ponds are a non-hazardous material. Thus, the material can be disposed of either on-site or in a landfill. The state law requires that BMPs be inspected annually. In practice, this typically does not occur because of resource limitations. The county has recently hired two more people to help with these inspections, but there are many BMPs in the county and the county does not anticipate achieving the annual inspection goal (Brush, 1995).

Typical oil/grit separators require much maintenance attention, and Montgomery County is trying to phase them out. The county has many sand filters proposed to replace the oil/grit separators, but information on their maintenance is not available due to the limited experience with cleaning and maintaining these filters (Brush, 1995).

State of Florida

The State of Florida does not have a specific regulation stating that each jurisdiction must dredge or remove material from BMPs periodically. They have issued a "Guidance Manual" as a supplement to the regulations which are considered inadequate for handling stormwater sediments for BMPs. Most BMPs were implemented in 1982, and are just to the point where they require dredging (Cox, 1995).

The guidance manual recommends testing of all BMP sediments, using the Toxicity Characteristics Leaching Procedure (TCLP), before disposal. The state has performed numerous analytical studies on this material, and in no cases was BMP sediment from any location determined to be hazardous. However, oil/grit separators were not tested as part of this study. Materials considered to be non-hazardous must have the appropriate laboratory TCLP paperwork before most landfills in Florida will accept it. Some cities and counties avoid this testing by sending BMP residuals to construction/debris landfills which are not as stringent. This practice is not supported by the state (Cox, 1995).

Even if a material is considered not hazardous using the TCLP test, the State of Florida also has a clean soil criterion. This is to protect community exposure from a material with elevated concentrations of a material which might not be classified hazardous. If a material does not pass the clean soil criterion, (e.g., if metal concentrations are high, but not hazardous) then it can only be used in an area where public access is controlled. Material such as this can be used as a landfill cover because public access is limited to most landfills. If the material does pass the TCLP and clean soil criterion then it can be used or disposed of in any manner. A beneficial use of the material is to blend it with soil as a conditioner (Cox, 1995).

Sediments from dry ponds in Florida are removed using a front-end loader and a dump truck. It is then recommended that a TCLP test be conducted on this material before either disposing on-site, landfilling, or disposing of in another manner. Wet ponds are dredged, however, these ponds are sometimes directly connected to a waterway so caution is taken to ensure solids are not resuspended in this operation. This material is usually spread out on the site to allow drying and disposed of on-site. If on-site disposal is not an alternative, then the sediments are usually transported to a landfill (Cox, 1995).

State of Delaware

The State of Delaware has followed Florida's lead as far as handling and disposal of stormwater BMP residuals. The State of Delaware has not conducted testing of stormwater BMP sediments, but considers the material as non-hazardous based on Florida's research and other research/reports. The state also has a stormwater management program in which local jurisdictions are required to inspect BMPs on an annual basis (Shaver, 1995).

The state's stormwater management plan includes BMP construction guidelines for ease of maintenance for the BMP and on-site disposal of the stormwater residuals. Oil/grit separators are not a BMP alternative in the State of Delaware. In addition to detention basins, sand filters are commonly used. The cleaning schedule for a sand filter is site specific, but three to four times a year is a general estimate. Three people are used to clean a "typical" Delaware Filter manually and shovel out the material which takes approximately 4 hours. Labor cost to clean the filter is approximately $120. The material is then transported to the landfill for disposal as this sediment was tested and not considered a hazardous material (Shaver, 1995).

State of Maryland

The State of Maryland conducted a four year study on oil/grit separators with the Metropolitan Washington Council of Governments. This study evaluated material from oil/grit separators in Maryland to determine if it was hazardous. The study also evaluated maintenance of oil/grit separators, as well as disposal of the residuals/solids from an oil/grit separator. Results from the study indicated that the solids from oil/grit separators were not hazardous, therefore, this material could be disposed of at a landfill after dewatering. However, as this material is site specific it was recommended that it be tested prior to sending to a landfill (Pencil, 1995).

Inspections of BMPs are required of all local jurisdictions. Every three years, the state reviews stormwater programs and procedures utilized by the local jurisdiction. The state has noted that many BMPs are not being properly maintained. This is due to cost and manpower requirements associated with regularly inspecting all BMPs by the local jurisdiction. Many homeowners' associations have BMPs on their property. Maintenance of these BMPs is another area of concern for the state because many homeowner's associations do not implement proper O&M procedures to maintain the BMP on their property (Pencil, 1995).

Sediments from wet ponds and dry ponds, as long as they are not hazardous, are usually dewatered and then disposed of on-site or landfilled. It is a common practice to spread this material out on a site for use as a soil amendment (Pencil, 1995).

SUMMARY OF FINDINGS

Data is available for solids content, nutrients, heavy metals, and other pollutants such as PCBs for many urban stormwater BMP solids/residuals. However, the data on stormwater residual's PAH and hydrocarbon concentrations is limited. Additional sampling and analysis would be beneficial to further examine these parameters.

Inspection and maintenance programs are the key to success for all BMPs. Guidelines for inspection and frequency of inspection are provided by most states for local jurisdictions. However, manpower requirements associated with enforcing the guidelines on the state level and inspection of these BMPs on the local level do not seem to be adequate. BMPs located on private property are not usually properly maintained or inspected. A possible solution to this lack of maintenance is to put a maintenance requirement in the deed for the land. This would require all owners of that property to properly maintain the BMP.

Difficulties in maintaining oil/grit separators and disposing of the residuals have resulted in some jurisdictions phasing their use out. Oil/grit separators require frequent maintenance and cleaning, the material is difficult to dewater, and the material is expensive to dewater, haul, and dispose of in a landfill (when the landfill accepts the material). Also, if oil/grit separators are not properly maintained then pollutants removed by the BMP can be released back into the stormwater.

Since many wet ponds and dry ponds were implemented in the 1980's, they have not required dredging or handling of the dredge material. Some local jurisdictions planned for on-site disposal of the material in the BMP design which is very cost effective because it avoids transportation charges. Local jurisdictions which did not plan for on-site disposal in the design of these BMPs are searching for disposal options for this material. Testing of stormwater sediment in many studies have indicated that this material is non-hazardous. Therefore, in most situations it can be disposed of on-site (land application or land disposal), in a landfill, or in an incinerator.

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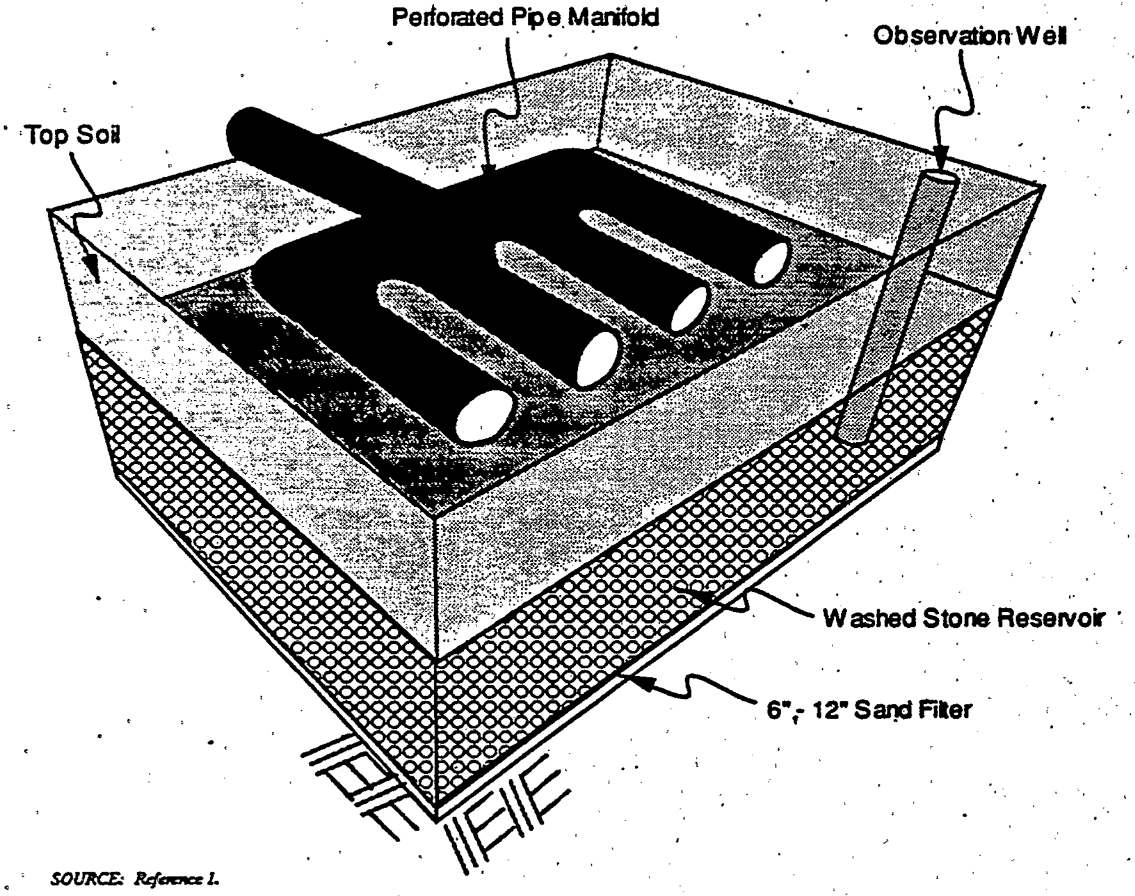
STORM WATER BMP: INFILTRATION DRAINFIELDS

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.

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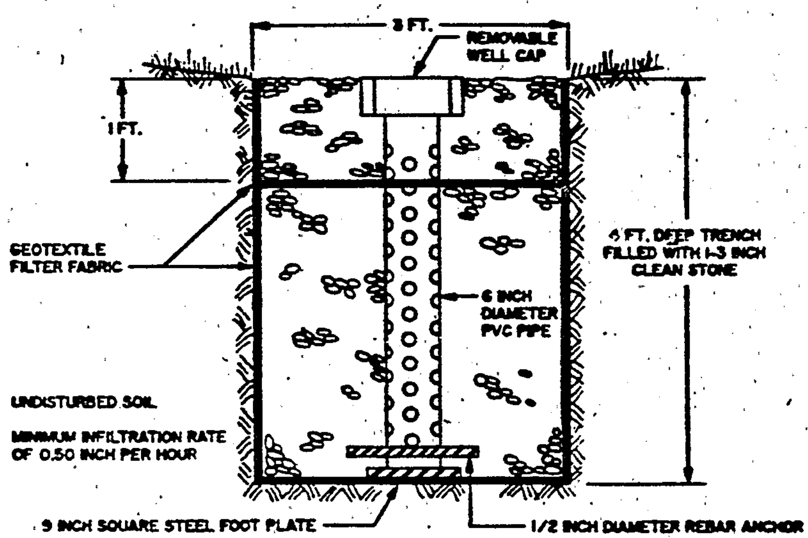
STORM WATER BMP: INFILTRATION TRENCH

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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6. Southeastern Wisconsin Regional Planning Commission (SEWRPC), 1991. Costs of Urban Nonpoint Source Water Pollution Control Measures. Technical Report No. 31.

7. United States Environmental Protection Agency (USEPA), 1991. Detention and Retention Effects on Groundwater, Region V.

8. Washington, State of, 1992. Storm Water Management Manual for the Puget Sound Basin (The Technical Manual), Department of Ecology.

This 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.

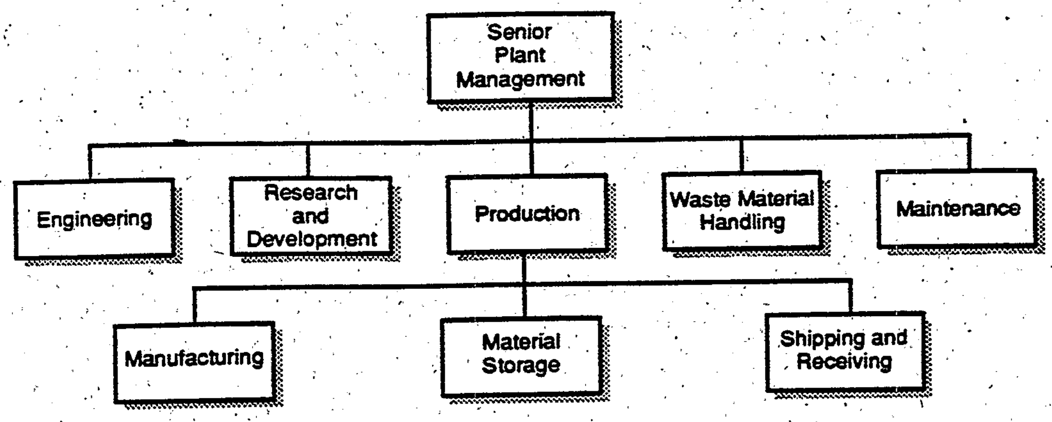
PERFORMANCE

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.

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

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.

Office of Wastewater Enforcement & Compliance
MUNICIPAL TECHNOLOGY BRANCH

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.

REFERENCES

1. Pitt, Robert, and Field, Richard, Non-Storm water Discharges into Storm Drainage Systems, NTIS Report No. PB92-158559, 1992.

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3. Gartner, Lee and Associates, Ltd., Toronto Area Watershed Management Strategy Study, Technical Report No. 1, Humber River and Tributary Dry Weather Outfall Study, Ontario Ministry of the Environment, Toronto, Ontario, November 1983.

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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.

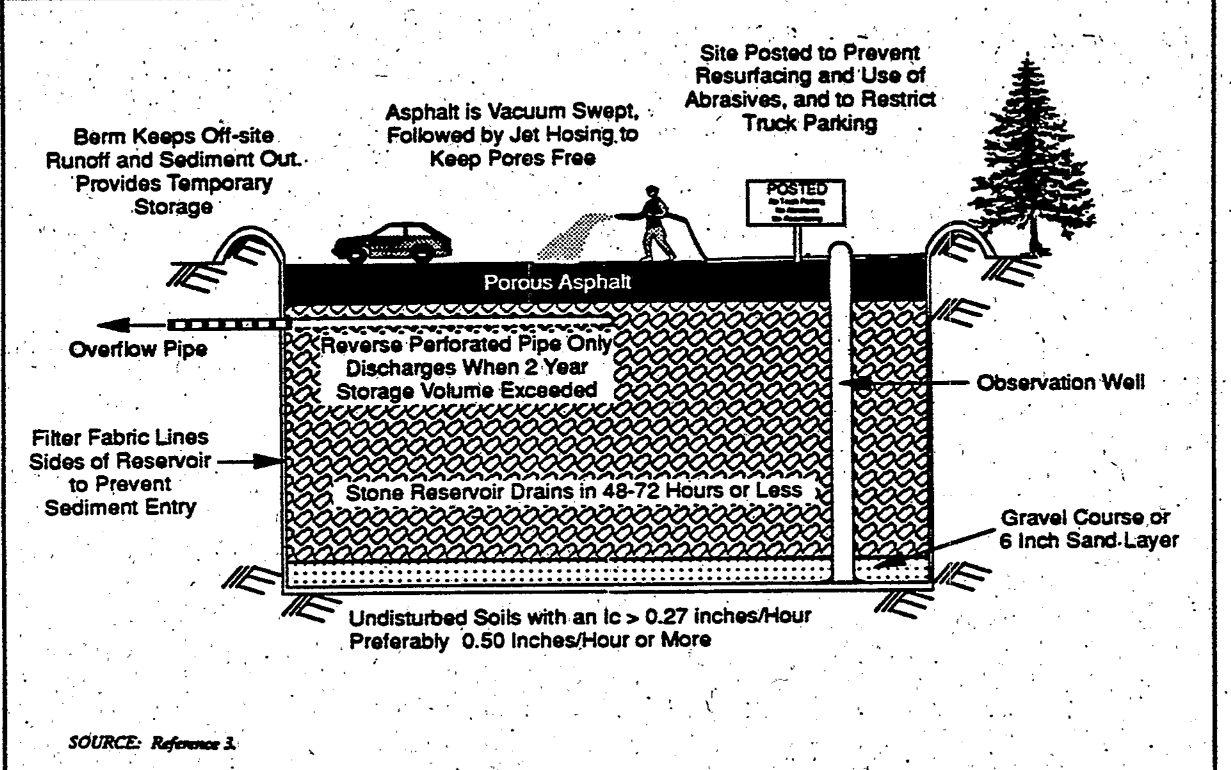

FIGURE 1: TYPICAL POROUS PAVEMENT INSTALLATION

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 use 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.

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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: 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.

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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

MTB
Office of Wastewater Enforcement & Compliance
MUNICIPAL TECHNOLOGY BRANCH

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 oil or hazardous substances in excess of reportable quantities.

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 Recovered	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 Recovered	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 Recovered	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.

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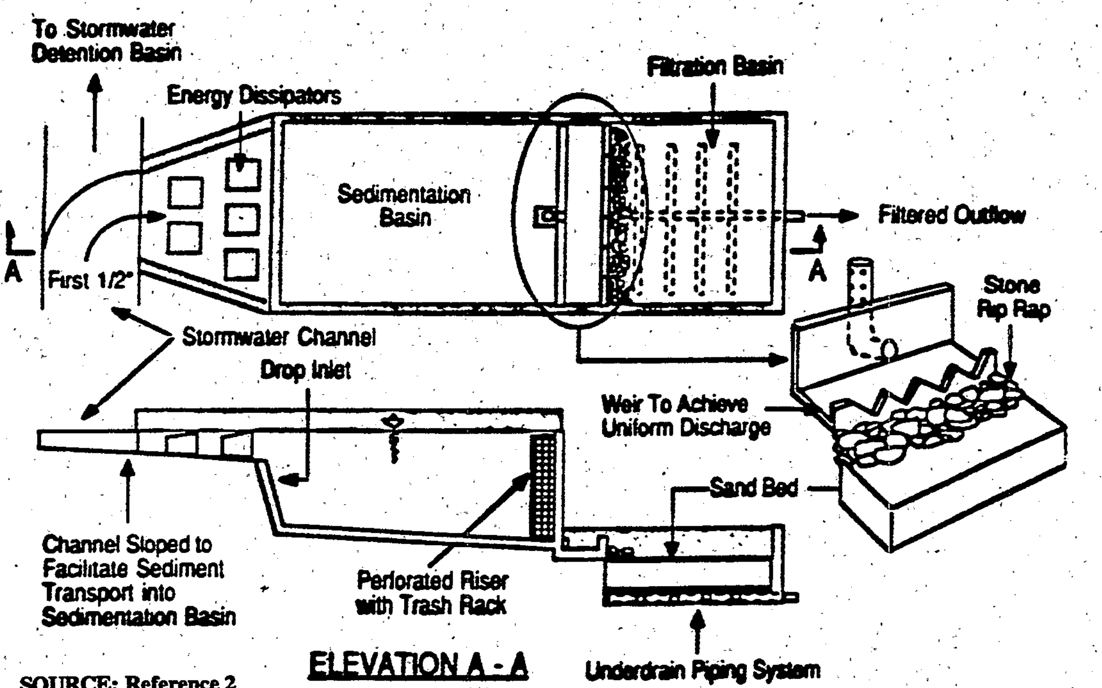
This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC 20460.

STORM WATER BMP: 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.

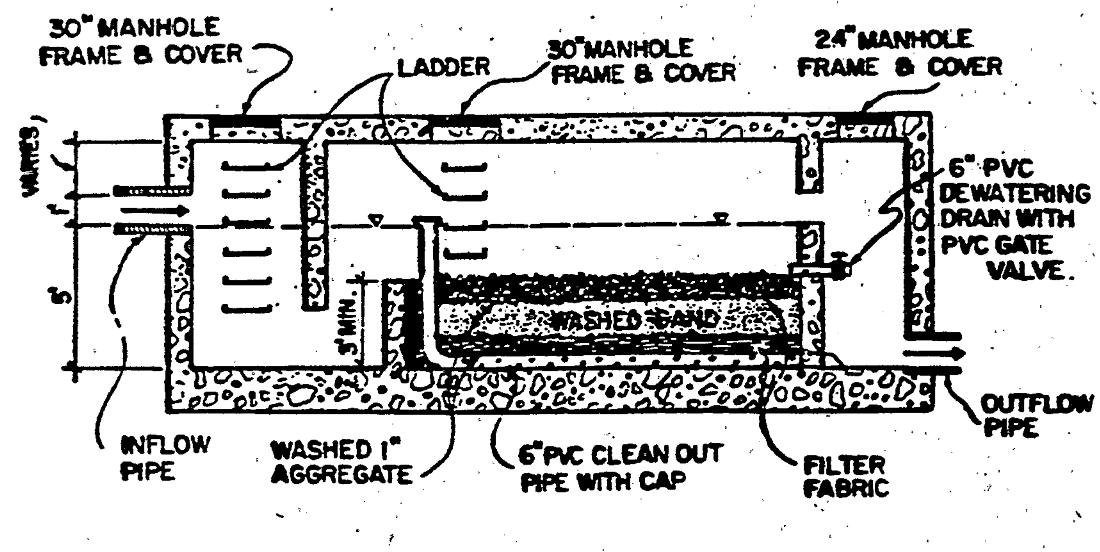


FIGURE 1b: TYPICAL WASHINGTON, DC SAND FILTER DESIGN

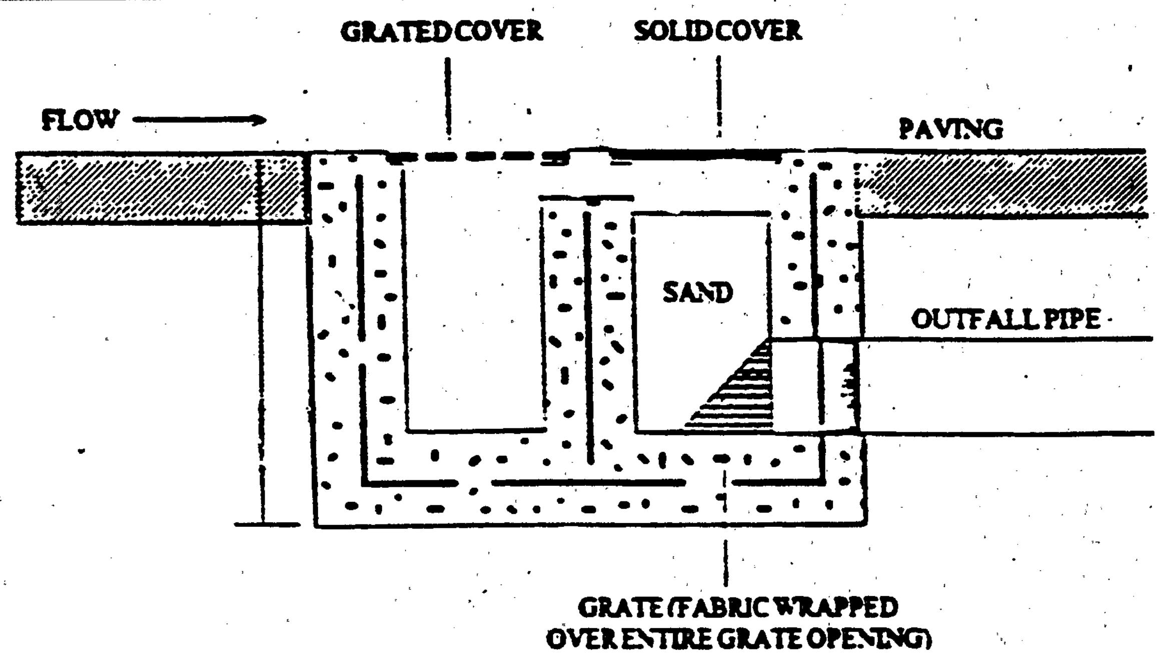


FIGURE 1c: TYPICAL DELAWARE SAND FILTER DESIGN

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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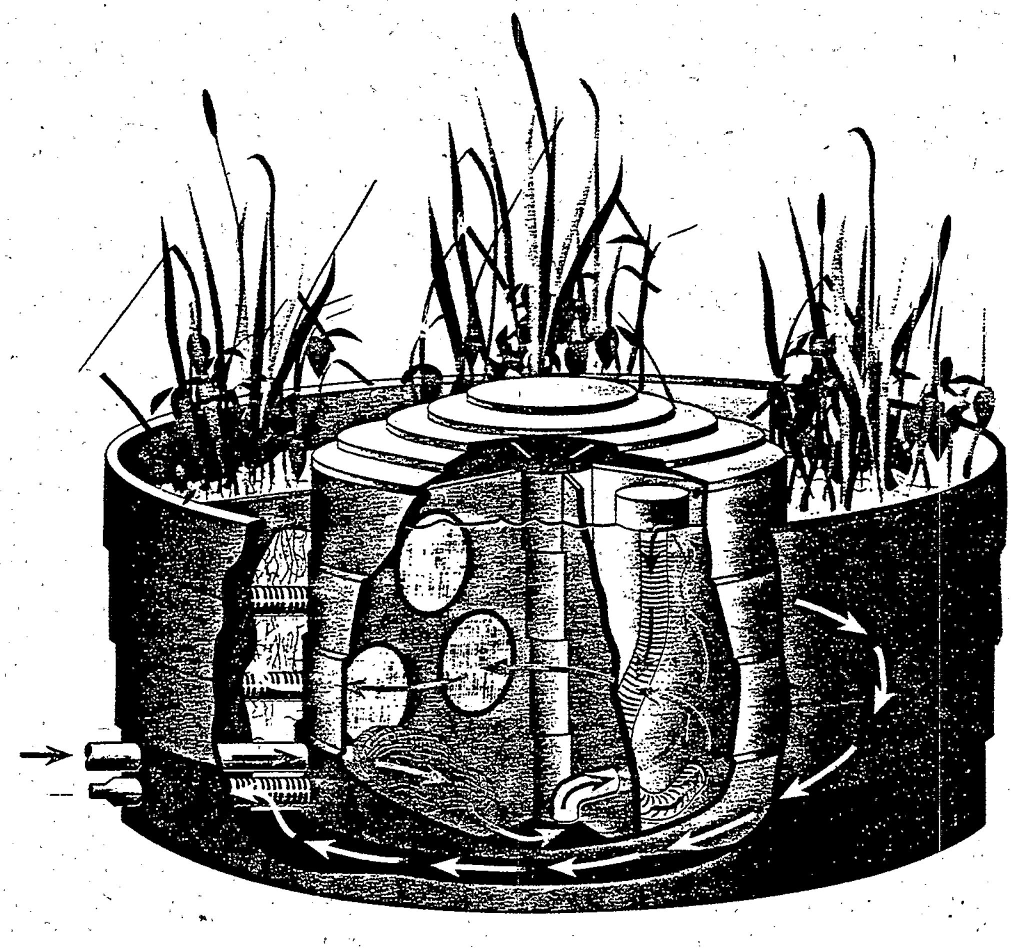
STORMWATER BMP:
STORMTREAT™ SYSTEM

DESCRIPTION

The STORMTREAT™ System (STS), developed in 1994, is a stormwater treatment technology consisting of a series of sedimentation chambers and constructed wetlands which are contained within a modular, 9.5-foot diameter recycled-polyethylene tank. The STS is shown in Figure 1. Influent is piped into the sedimentation chambers where pollutant removal processes such as sedimentation and filtration occur. Stormwater is conveyed from the sedimentation chambers to a fringing constructed wetland where it is retained for five to ten days prior to discharge. Unlike most constructed wetlands for stormwater treatment, the stormwater is conveyed into the subsurface of the wetland and through the root zone. It is within the root zone that greater pollutant attenuation occurs through processes such as filtration, adsorption, and biochemical reactions.

FIGURE 1 STORMTREAT™ SYSTEM



Source: StormTreat Systems, Inc.

COMMON MODIFICATIONS

The STS design allows for modifications when the system is installed in areas with high groundwater levels or in areas tidally affected. In areas with high groundwater, modifications to the discharge pipe work can be made so that runoff is discharged to a remote downgradient area with a lower water table level. In tidally influenced areas, a check valve can be installed to prevent flow from reentering the unit from its discharge point after the flow has discharged and allow discharge only during mid to low tide conditions. The valve would be adjusted for higher than normal flow velocities (those velocities used with a non-tidally influenced unit) so that the system maintains an average holding time of five to ten days.

The manufacturers of the system indicate that the STS could be used throughout the US, with only minor modifications to the system to make it effective in different geographical areas. In cold climates, where the 4 foot height unit would be installed above the frost line, modifications may be necessary to prevent the water within the tank from freezing. Adding a greenhouse to cover the system or insulating the subgrade tank may prove to be effective.

Modifications may also be necessary in an arid region due to insufficient water to support the wetland vegetation. In these areas the unit could be modified to discharge the flow at a slower rate which would increase the water retained in the bottom of the unit. Soils that retain water more efficiently could also be used. Alternately, the unit could have an alternate water supply for the extended dry periods.

CURRENT STATUS

An STS has been installed in Kingston, Massachusetts (MA) and has been operational since November 1994. The need for a stormwater treatment system in this area became evident as increased bacteria levels caused the closing of shellfish beds in the Jones River. Additional systems are planned for installation in Gloucester, MA, Harwich, MA, and Waltham, MA. Two systems will be installed in Gloucester to help mitigate impacts to the downstream shellfish beds which have also been identified as having high counts of fecal coliform bacteria. The system planned for installation in Harwich will treat polluted runoff from the town landing prior to discharge to Wychmere Harbor, a scenic boating harbor on Cape Cod. A system will be installed at GTE in Waltham during the Fall of 1995. The industrial complex is located in a sensitive watershed. The system will collect rooftop runoff and runoff from a parking lot. If these installed systems prove to be cost effective, there are additional needs in Massachusetts where 40 percent of the shellfish beds have been closed due to high levels of metals and bacteria.

APPLICATIONS

The STS has applications in a wide range of settings. The system's size and modular configuration make it adaptable to a wide range of site constraints and watershed sizes. Designers of the system indicate that the system can be used to treat runoff from highways, parking lots, airports, marinas, and commercial, industrial and residential areas. The STS is an appropriate stormwater treatment technology for both coastal and inland areas.

LIMITATIONS

As discussed previously, the STS is relatively new and untested in different geographical locations. There may be possible limitations in these areas. Soil types surrounding the modular unit will not limit the system's effectiveness nor will high water tables.

PERFORMANCE

Preliminary monitoring results from four sets of samples collected in November 1994, December 1994, and February 1995 indicate removal rates of 94% for total coliform bacteria, 83% for fecal coliform bacteria, 95% for total suspended solids, and 90% for total petroleum hydrocarbons, as shown in Table 1. Preliminary nutrient removal rates have been determined to be 44% for total dissolved nitrogen, 89% for total phosphorus (TP), and 32% for ortho-phosphorus. Total nitrogen (TN) performance data are not available at this time; however, the manufacturer of the system indicates that they should be high based on the results of other wetland systems where particulates, and therefore TN, are removed. Removal rates are anticipated to increase as the wetland vegetation becomes more established and during warmer months. The pollutant removal rates achieved by the system for other pollutants are as follows: 65% for lead, 98% for chromium, and 90% for zinc.

TABLE 1 STORMTREAT™ MONITORING RESULTS

Pollutant	Percentage Removed
Total Coliform Bacteria	94
Fecal Coliform Bacteria	83
Total Suspended Solids	95
Chemical Oxygen Demand	75
Total Dissolved Nitrogen	44
Total Phosphorus	89
Ortho-phosphorus	32
Total Petroleum Hydrocarbons	90
Lead	65
Chromium	98
Zinc	90

DESIGN CRITERIA

The STS is a modular, 9.5-foot diameter recycled-polyethylene tank containing a series of sedimentation chambers and constructed wetlands. The sedimentation chambers are in the inner ring of the tank, which has a diameter of nearly 5.5 feet. The 9.5 feet diameter outer ring, which surrounds the sedimentation chambers, contains the wetland. The tank walls and bulkheads, which separate the sedimentation chambers, have a height of 4 feet.

The STS tanks are designed to withstand the hydrostatic pressures that result from the saturated soils surrounding the tanks. The STS unit connects to existing catch basins with PVC piping. Influent is conveyed through the PVC piping to the first of six internal sedimentation chambers. The 4 inch diameter inlet pipe is covered with a burlap sack that traps larger particles and debris. Synthetic screens and woven geotextiles placed within the bulkheads filter the flow as it passes into the succeeding chamber. Flow is conveyed through larger mesh sizes in the first series of sedimentation chambers, followed by smaller mesh sizes in the remaining sedimentation chambers. In addition to the filter screens, skimmers have been installed in the tanks. Skimmers replace the previously used screens and combination of screens and skimmers. The screens and skimmers perform the same pollutant removal mechanism; however, the screens require more maintenance than the skimmers. The skimmers float on the water surface within each chamber and have an opening 6 inches below the surface through which flow is conveyed to the following tank. Sediments which collect in the bottom of the chamber remain in that chamber until the unit is maintained. The skimmers prevent sediment from being conveyed to the subsequent chamber. The bulkhead separating the last two sedimentation chambers is fitted with an inverted elbow which traps oil and grease within the fifth chamber. The elbow is located approximately 10 inches from the chamber bottom.

Flow is conveyed from the sedimentation chamber through four, 4 inch diameter, PVC, slotted outlet pipes into the wetland portion of the STS. Stormwater flows subsurface through the length of the wetland, which has a length of 23 feet, width of 2.4 feet, and contains 3 feet of gravel and sand. The gravel used at the Kingston facility is 1/4 inch rice stone and 3/8 inch bluestone. The weight of the gravel provides the force that counteracts the buoyancy forces that would be present at a high water table site. The wetland has an approximate storage capacity of 760 gallons. The entire system has a capacity of 1,390 gallons.

Vegetation within the wetland will vary depending on the local, naturally occurring wetland vegetation and the maximum expected root depth of the plant. Bulrush and burreeds have been used in Massachusetts and have maximum root depths of 2.6 and 2 feet, respectively (USEPA, 1993). Mature vegetation should have roots that extend into the permanent 6 inches of water in the bottom of the tank. Insufficient root depth may result in a lack of water supply to the plants during the periods between storm events.

Effluent from the wetland is discharged through a 2 inch diameter pipe that is controlled by a valve. Flow rates and holding times can be varied by manipulating the outlet control valve. At the Kingston facility, the control valve is adjusted to provide for a recommended discharge rate of 0.2 gal/min. and a 5-day holding time in the wetland. The valve has an added benefit that in the event of an upstream toxic spill the valve can be closed and the pollutants will be trapped in the STS.

Tanks are available in one size but multiple tanks can be installed at a site to capture the volume of runoff from the site. The size of the tank was selected so that the prefabricated tanks could be transported without requiring conformance to oversized load regulations. The determination of the number of tanks needed for a site is based on three factors:

- Area of impervious drainage surfaces;
- Design storm to be treated; and
- Detention storage prior to the STS tanks.

To capture and treat the first 0.25 inches of runoff from a one acre, completely impervious drainage area, the designers of the system estimate that two tanks would be required when preliminary detention is provided and five tanks when it is not. For a design storm of 0.5 inches, four tanks are required with preliminary detention and ten tanks without preliminary detention. Preliminary detention may be provided in the drainage pipes and catch basins which convey flow to the STS. In some instances, settling tanks may be located upstream that detain the runoff. A typical site would require 100 ft^2 per tank, which includes sufficient space for the tank and access to the tank for maintenance.

MAINTENANCE

Anticipated maintenance of the STS is minimal. The system should be observed at least once a year to be sure that it is operating effectively. At that time the burlap sack that covers the influent line should be removed and replaced. If the system installed uses filters, these should be removed, cleaned, and reinstalled. Sediment should be removed from the system once every 2 to 3 years, unless the system has higher than normal sediment loads. After six months of operation the unit installed in Kingston, MA was found to have 2 inches of accumulated sediment. The sediment can be pumped from the tank by septic haulers or by maintenance personnel responsible for sediment removal from catchbasins. It is not anticipated that the sediment will be toxic and may be safely landfilled. However, sediment toxicity will depend on the activities in the contributing drainage area and testing of the sediment may be required to determine if it should be considered hazardous.

COSTS

The STS is a prefabricated unit that is easily installed in most locations. Installation time for a normal site (i.e., bedrock not encountered) is approximately four man-days. This time includes both site preparation and installation. The estimated cost for one installed tank is $3,600 to $4,000, which includes the site work, tank, skimmers, gravel, wetland plants, external PVC piping, and installation by the manufacturer. Costs of systems that have been installed or are planned for installation have been lower that the estimated costs due to the municipalities providing the site preparation at no charge. The higher end of the cost range may be encountered if complications with site preparation occur. Capital and installation costs decrease as the number of units on a site increases. The cost for a system installed by the manufacturer and consisting of four tanks is approximately $15,000. The four tank system would effectively treat a one acre, completely impervious drainage area with preliminary detention designed to capture the first 0.5 inches of runoff.

The estimated maintenance cost for removal of sediment from one tank ranges from $100 to $150. This cost is incurred every two to three years when sediment removal is necessary. Costs have not been determined for an annual site inspection and removing any debris and leaves from the wetland area. However, these costs should be minimal (i.e., one day of labor for one person).

ENVIRONMENTAL IMPACTS

Systems have been installed in Massachusetts due to the increased bacteria levels resulting in the closing of shellfish beds. Regulators and environmental groups in Massachusetts are concerned over the closing of 40 percent of the shellfish beds in the state and are utilizing stormwater management practices, including the STS, to improve the water quality in the downstream beds. The STS also protects the groundwater by removing pollutants prior to infiltration. The STS has shown high TPH, TP, metals, and suspended solids removal rates, which improves water quality. An additional benefit of the STS is the system's spill containment feature which results in capture of an upstream release, and therefore, lessens the impact from the spill on the environment.

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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

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.

- 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.

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.

MTB
Office of Wastewater Enforcement & Compliance
MUNICIPAL TECHNOLOGY BRANCH

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

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MTB
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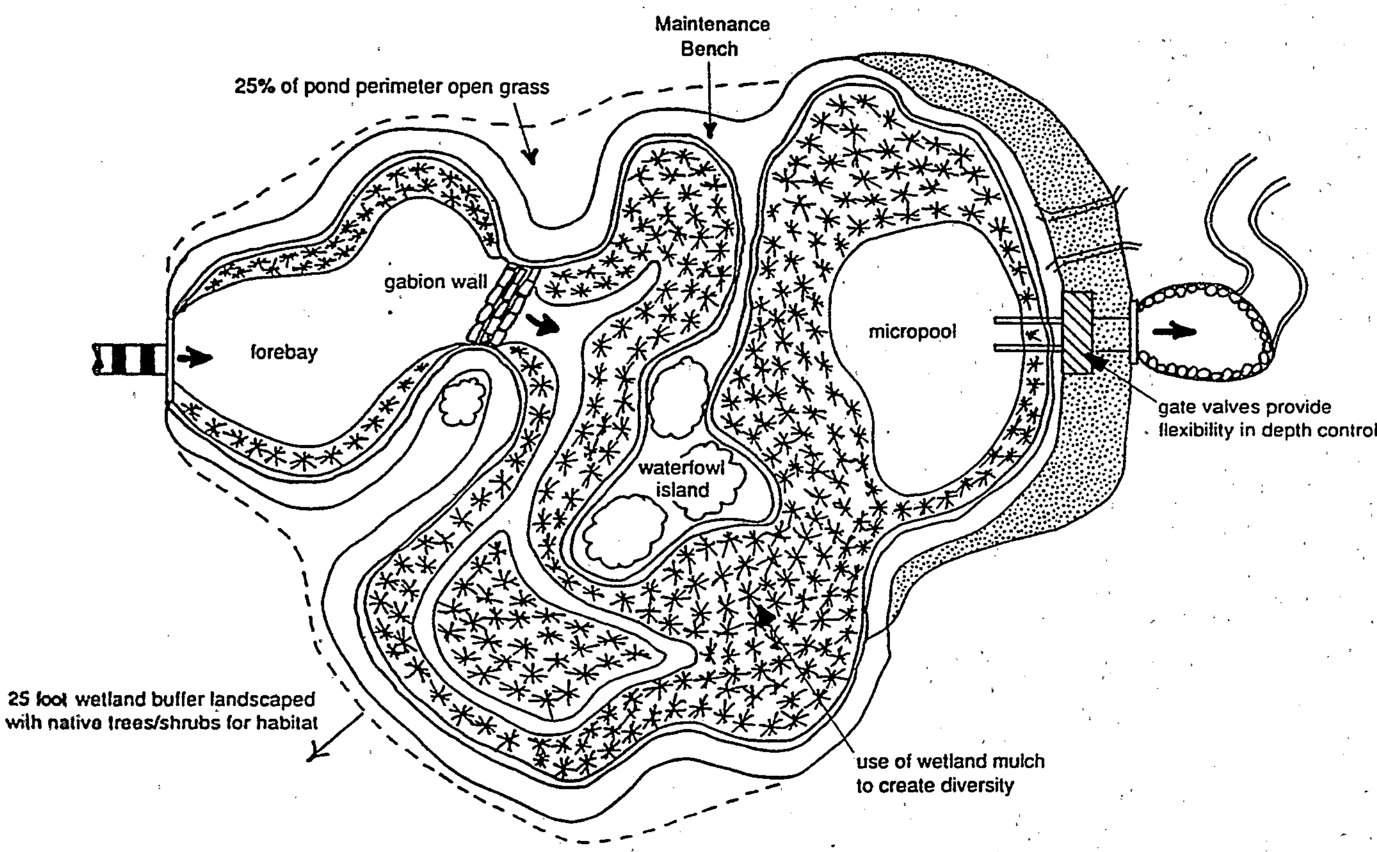
MUNICIPAL TECHNOLOGY BRANCH

STORMWATER BMP:
STORMWATER WETLANDS

DESCRIPTION

Wetlands are those areas that are typically inundated with surface or ground water and support plants adapted to saturated soil conditions. A typical shallow marsh wetland is shown in Figure 1. Wetlands have been described as "nature's kidneys" due to the physical, chemical, and biological processes that occur in wetlands which result in transformation of some elements (e.g., nitrogen, sulfate) and filtration of others (Hammer, 1989). The natural pollutant removal capabilities of wetlands have brought increased attention to their usage as a stormwater best management practice (BMP).

FIGURE 1 SHALLOW MARSH WETLAND



Source: MWCOG, 1992.

Wetlands used for stormwater treatment can be constructed, incidental or natural. Incidental wetlands are those that were created as a result of previous development or human activities. The use of natural wetlands for stormwater treatment is discouraged by many and may not be an option. Some states, however, allow their usage but only in very restricted circumstances. For example, the State of Florida allows the use of natural wetlands that have been severely degraded or wetlands that are intermittently connected (flows when groundwater rises above ground level) to other waters (Livingston, 1994). Conversion of natural wetlands to stormwater wetlands are done on a case-by-case basis and require the appropriate state and federal permits (e.g., 401 water quality certification and 404 wetland permit).

Two types of constructed wetlands have been used successfully for wastewater treatment: the subsurface flow (SF) and the free water surface (FWS) constructed wetland. In the FWS wetland runoff flows through the soil lined basin at shallow depths. The wetland consists of a shallow pool planted with emergent vegetation (vegetation which is rooted in the sediment but the leaves are at or above the water surface). The SF wetland also has a basin, however, the basin contains a suitable depth of rock or gravel, through which the runoff is conveyed. The water level in a SF wetland remains below the top of the rock or gravel bed. Studies have indicated that the SF wetland is well suited for the diurnal flow pattern of wastewater, however, the peak flows from stormwater or combined sewer overflows (CSO) may be several orders of magnitude higher than the average flow. The cost for a gravel bed to contain the peak storm event would be very high, and therefore, preclude the use of SF wetlands for stormwater or CSO treatment. The remainder of this factsheet addresses the FWS constructed wetland or natural and incidental wetlands.

COMMON MODIFICATIONS

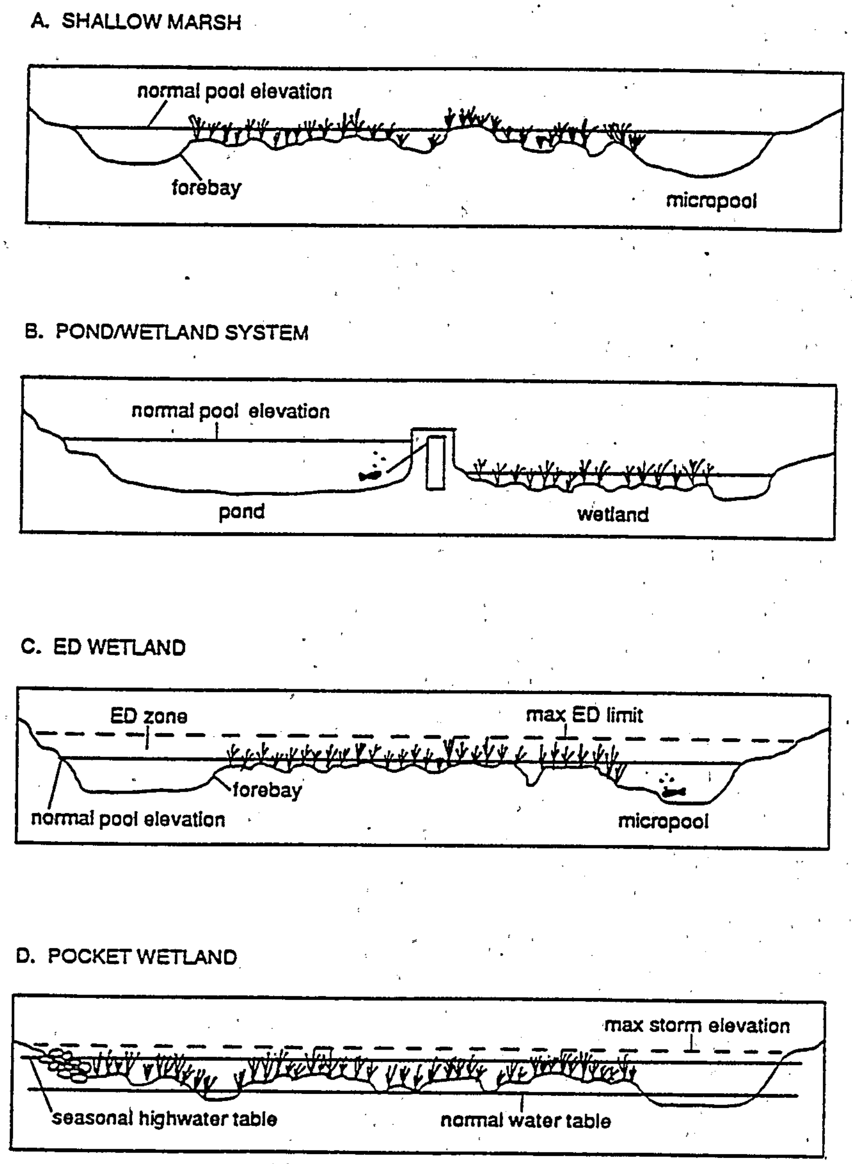
There are four basic designs of constructed wetlands: shallow marsh, pond/wetland system, extended detention (ED) wetland, and pocket wetland. The wetland designs, as shown in Figure 2, store runoff in a shallow basin vegetated with wetland plants. The selection of one design over the other will depend on various factors, including the land availability, level and reliability of pollutant removal, and size of contributing drainage area. The shallow marsh design requires the largest amount of land and a sufficient baseflow to maintain water within the wetlands. The marsh can be modified to include extra vertical runoff storage. This modified marsh system, known as the ED wetland, attenuates flows and relieves downstream flooding.

Another variation, the pond/wetland system, has two separate cells: one being a wet pond and the other a shallow marsh. The wet pond traps sediments and reduces velocities prior to runoff entry into the wetland. Land requirements for a pond/wetland system are less than for the shallow marsh system. Areas with insufficient land area for construction of a larger wetland system, may be appropriate sites for the fourth wetland design, a pocket wetland. Pocket wetlands have contributing drainage areas of 1 to 10 acres and usually will require excavation down to the water table in order to provide a reliable water source to the wetland. Unreliable water sources and fluctuating water levels result in low plant diversity and poor wildlife habitat value (MWCOG, 1992).

CURRENT STATUS

In the past the use of natural treatment processes occurring within wetlands has generally focused on the the treatment of wastewater. Wetlands for stormwater treatment have gained attention in recent years and many systems are now operational. Studies are ongoing to determine the effectiveness of wetlands, design modifications that improve their performance, and required maintenance to sustain their performance.

FIGURE 2 COMPARATIVE PROFILES OF FOUR STORMWATER WETLAND DESIGNS



Cross-sectional profiles of the four stormwater wetlands are not drawn to scale. In Panel A, the majority of the shallow marsh is devoted to shallow depths that support emergent wetland plants. The pond/wetland system (Panel B) is composed of deep and a shallow pool. In ED wetlands (Panel C), the runoff storage of the wetland is augmented by temporary, vertical ED storage. Pocket wetlands (Panel D) are excavated to the groundwater table to provide a more or less constant water elevation.

Source: MWCOG, 1992.

APPLICATIONS

Wetlands provide the benefit of stormwater quality control, with the option of achieving quantity control (e.g., extended detention wetland). Wetlands are one of the more reliable BMPs capable of removing pollutants and are adaptable to most locations in the US. Locations with existing wetlands used for stormwater treatment include, but are not limited to, Washington, California, Minnesota, Michigan, Illinois, Florida, Maine, Maryland, and Virginia. They have been used to treat runoff from agricultural, commercial, industrial, and residential areas.

LIMITATIONS

Urban settings and established communities may preclude the use of wetlands due to the large land requirement for the systems. The presence of trout, sculpins and other temperature sensitive fish species or aquatic insects located in downstream waters may also preclude the use of wetlands due to the stream warming that could occur within a wetland, especially during the warmer months. Communities may be opposed to a wetland due to their preconceived notion that wetlands will result in an infestation of mosquitoes and other nuisances. Communities may also be opposed due to the appearance of the wetlands. Wetlands, however, can be designed to be attractive and features (e.g., morphology, fish, and vegetation) can be added to decrease, if not eliminate, a problem with mosquitoes and other nuisances.

Limitations in pollutant removal may be experienced during the non-growing season and in localities with lower temperatures. Decreases in pollutant removal efficiency have been observed when wetlands are covered with ice or receive snowmelt runoff.

PERFORMANCE

Stormwater pollutant removal in wetlands is attributed to the physical, chemical, and biological processes that occur within the wetland. Chemical and physical assimilation mechanisms include sedimentation, adsorption, filtration, and volatilization. Sedimentation is the primary removal mechanism for pollutants such as suspended solids, particulate nitrogen, and heavy metals. The settling of the particulates is influenced by the velocity of the runoff through the wetland, the particle size, and turbulence. Sedimentation can be maximized by creating sheet flow conditions, slowing the velocities through the wetland, and providing morphology and vegetation conducive to settling. The vegetation and its root system will also decrease the resuspension of settled particles.

Adsorption is the process where pollutants attach to surfaces of suspended or settled sediments and vegetation. Adequate contact time between the surface and pollutant must be provided for in the design of the system for this removal process to occur. Pollutants removed by adsorption include metals, phosphorus, and some hydrocarbons.

Wetland plants act as filters for pollutants such as trash, debris, and other floatables. Filtration can be enhanced by slow velocities, sheet flow, and sufficient quantities of vegetation. The plants also increase the pollutant removal achieved through sedimentation, adsorption, and microbial activity by providing for an increased detention and contact time and a surface for microbial growth.

Volatilization plays a minor role in pollutant removal from wetlands. Pollutants such as oils, hydrocarbons, and mercury can be removed from the wetland via evaporation or by aerosol formation under windy conditions.

Biological processes that occur in wetlands result in pollutant uptake by wetland plants and algae. Emergent wetland plants uptake settled nutrients and metals through their roots. The process creates new sites in the sediment for pollutant adsorption. During the fall the above ground parts typically die back and the plants may potentially release the nutrients and metals back into the water column (MWCOG, 1992). Recent studies, however, indicate that most pollutants are stored in the roots of aquatic plants, rather than the stems and leaves (CWP, 1995). Additional studies are required to determine the extent of pollutant release during the fall die back.

Microbial activity contributes to the removal of nitrogen and organic matter. Nitrogen is removed by nitrifying and denitrifying bacteria and aerobic bacteria are responsible for the decomposition of the organic matter. Microbial processes require oxygen and can result in depleted oxygen levels in the top layer of wetland sediments. The low oxygen levels and the decomposed organic matter contribute to the immobilization of metals.

Soluble pollutants such as phosphorus and ammonia are partially removed by planktonic or benthic algae. The algae consume the nutrients and convert it into biomass. The biomass settles to the bottom of the wetland.

Evaluation of the removal effectiveness of wetlands is ongoing and limited data are currently available; however, some conclusions can be drawn from available preliminary data. The projected long term pollutant removal rates for constructed wetlands in the Mid-Atlantic Region as reported by MWCOG (1992) and Strecker (1995) are presented in Table 1. As shown, total suspended solids (TSS) and lead removal rates are anticipated to approach 75 percent. Lower removal rates are expected for nutrients and organic carbon. The removal rates will vary with the loadings to the wetland. Excessive pollutant loadings (e.g., suspended solids) may exceed the wetlands removal capabilities.

TABLE 1 PERFORMANCE OF STORMWATER WETLANDS (1)

Pollutant	Removal Rate
Total Suspended Solids	75 %
Total Phosphorus	45 %
Total Nitrogen	25 %
Organic Carbon	15 %
Cadmium (2)	70%
Copper (2)	40%
Lead	75%
Zinc	50%
Bacteria	2 log reduction

(1) Source: MWCOG, 1992
(2) Source: Strecker, 1995

Conclusions have been determined from studies performed on wetlands with regard to their effectiveness compared to other BMPs and construction practices that affect performance. Data indicate that the pollutant removal achieved with wetlands is similar to that achieved with conventional pond systems. Studies also indicate that constructed stormwater wetlands achieve higher pollutant removal rates than natural wetlands. This is likely due to the intricate design of the constructed systems and the continued monitoring and maintenance of the systems (MWCOG, 1992). The effectiveness of the wetland seems to improve after the first few years of use as the vegetation becomes established and organic matter accumulates in the wetland. During construction and excavation, many constructed wetlands lose organic matter in the soils. The organic matter provides exchange sites for pollutants, and therefore, plays an important role in pollutant removal. Replacing or adding organic matter after construction improves performance.

LONGEVITY

Well designed wetlands can function as designed for 20 years or longer. Accumulated sediments will gradually cause a decrease in storage and performance, and therefore, should be removed as necessary or the water level in the wetland should be raised (e.g., adjust outlet to increase discharge elevation). Sediment forebays will decrease the accumulation of sediments within the wetland and increase the wetlands longevity.

DESIGN CRITERIA

Required local, state and federal permits should be established prior to wetland design with the appropriate regulatory authorities. Required permits and certifications may include 401 water quality certifications, 402 stormwater NPDES permit, 404 wetland permits, dam safety permits, sediment and erosion control plans, waterway disturbance permits, forest clearing permits, local grading permits, and land use approvals.

Prior to construction, a site should be selected that is appropriate for a wetland. The site must have an adequate water balance and appropriate underlying soils. This requires that the baseflow from the drainage area or groundwater is sufficient to maintain a shallow pool in the wetland and support the vegetation. Certain species are more susceptible to damage during dry periods. Underlying soils that are type B, C, or D will have relatively insignificant infiltration losses. High infiltration rates may be experienced at sites with type A soils or at sites underlain by karst, limestone, or fractured bedrock. These sites may require geotextile liners or a 6 inch layer of clay. After any necessary excavation and grading of the wetland at least 4 inches of soil should be applied to the site. This material may be the soil previously excavated or sand and other suitable material. The soils are needed to provide a substrate that the vegetation can become established in and anchor to. The substrate should be soft for ease of insertion of the plants.

The Metropolitan Washington Council of Governments (MWCOG) has made recommendations for the design of wetlands that require the designer to meet several basic sizing criteria. The volume of the wetland is determined as the quantity of runoff generated by 90 percent of the runoff producing storms. This volume will vary throughout the US due to the different rainstorms experienced. In the Mid-Atlantic Region, for example, the 1.25 inch storm is used as the sizing criterion. The imperviousness of a watershed will impact the runoff volume generated. The following equations are used to determine the treatment volume (Vt):

(1) $Rv = 0.05 + 0.009\,(I)$

where:

Rv = storm runoff coefficient

I = percent site imperviousness

(2) $Vt = [(1.25)(Rv)(A)/12](43{,}560)$

where:

Vt = treatment volume (ft^3)

A = contributing area (acres)

Sizing criteria for wetlands vary with some states having their own methods. For example, shallow wetland basins constructed in Maryland are designed to maximize the surface area. The surface area should be a minimum of 3 percent of the area of the watershed draining to it. The preferred design would include extended detention, the volume of which is determined by detaining the 1-year storm for 24 hours. The Washington State Department of Ecology sizes wetlands using the runoff generated from the 6-month, 24-hour rainfall event.

Criteria are also established by MWCOG for the water balance, maximum flow path, allocation of treatment volume, minimum surface area, allocation of the surface area, and extended detention. The water balance, as discussed previously, must be adequate during dry weather to provide a baseflow and maintain the vegetation. The flow path should be maximized to increase contact time between the plants and sediments and the runoff. The recommended length to width ratio is 2:1. A ratio of greater than 1:1 should prevent short circuiting where runoff escapes treatment. Suggested allocation of treatment volumes, as shown in Table 2, are provided to improve removal efficiency. The minimum surface area requirement for shallow marshes established by MWCOG is that the wetland to watershed area ratio be greater than 2 percent. The remaining three wetland designs can have wetland to watershed ratios greater than 1 percent.

TABLE 2 GUIDELINES FOR ALLOCATING WETLAND SURFACE AREA AND TREATMENT VOLUME

Target Allocations	Shallow Marsh	Pond/Wetland	ED Wetland	Pocket Wetland
Percent of Surface Area (%)				
Forebay	5	0	5	0
Micropool	5	5	5	0
Deepwater	5	40	0	5
Low Marsh	40	25	40	50
High Marsh	40	25	40	40
Semi-Wet	5	5	10	5
Percent of Treatment (%) Volume				
Forebay	10	0	10	0
Micropool	10	10	10	0
Deepwater	10	60	0	20
Low Marsh	45	20	20	55
High Marsh	25	10	10	25
Semi-Wet	0	0	50	0

Source: MWCOG, 1992
Deepwater - 1.5 to 6 feet below normal pool
Low Marsh - 6 to 18 inches below normal pool
High Marsh - 0 to 6 inches below normal pool
Semi-Wet - 0 to 2 feet above normal pool (includes ED)

The wetland surface area is allocated to four different depth zones: deepwater (1.5 to 6 feet), low marsh (18 to 6 inches below normal pool), high marsh (up to 6 inches below normal pool), and semi-wet areas (above normal pool). The allocation to the various depth zones will create a complex internal topography. This is important because various wetland plants have different depth requirements, therefore the internal complexity should maximize plant diversity and increase pollutant removal. Allocation guidelines established by MWCOG are shown in Table 2. The State of Maryland requires that 75 percent of the shallow marsh should have depths less than 12 inches and the remaining 25 percent should have depths ranging from 2 to 3 feet. The 75 percent portion is additionally broken down so that 25 percent ranges from 6 to 12 inches and the remaining 50 percent is 6 inches or less.

Extending detention within the wetland increases the time for sedimentation and other pollutant removal processes to occur and also provides for attenuation of flows. Up to 50 percent of the wetland treatment volume can be added into the wetland system for extended detention. The ED elevation should not, however, exceed 3 feet above the normal pool elevation. This will prevent large fluctuations in the water level that could potentially harm the vegetation. The ED volume should be detained between 12 and 24 hours.

Sediment forebays are recommended to decrease the velocity and sediment loading to the wetland. The forebays provide additional benefits of creating sheet flow, extending the flow path, and preventing short circuiting. The volume of the forebay should be at least 10 percent of the wetland treatment volume and have a depth of 4 to 6 feet. The State of Maryland recommends a depth of at least 3 feet. The forebay is typically separated from the wetland by gabions or an earthen berm (MWCOG, 1992).

Flow from the wetland should be conveyed though an outlet structure that is located within the deeper areas of the wetland. Discharging from the deeper areas using a reverse slope pipe prevents the outlet from becoming clogged. A micropool can be constructed where the outlet structure is to be located that will also prevent outlet clogging. The micropool should contain approximately 10 percent of the treatment volume and be 4 to 6 feet deep. An adjustable gate controlled drain capable of dewatering the wetland within 24 hours should be located within the micropool. A typical drain may be constructed with an upward facing inverted elbow with its opening above the accumulated sediment. The dewatering feature eases planting and follow-up maintenance (MWCOG, 1992).

Vegetation can be established by one of five methods: mulching, allowing volunteer vegetation to become established, planting nursery vegetation, planting underground dormant parts of a plant, and seeding. Donor soils from existing wetlands can be used to establish vegetation within a wetland. This technique, known as mulching, has the advantage of quickly establishing a diverse wetland community. However, the types of species that grow within the wetland is unpredictable with mulching. Another unpredictable technique is allowing the species to voluntarily become established. Wind and waterfowl provide volunteer species to wetlands. Volunteer species are usually well established within 3 to 5 years. Wetlands established with volunteers are usually characterized by low plant diversity with monotypic stands of exotic or invasive species. A higher diversity wetland can be established when nursery plants or dormant rhizomes are planted. Planting of the vegetation from a nursery should take place during the growing season and not during late summer and fall. Planting during the growing season gives the vegetation time to store up food reserves in the underground parts for the dormant period. Underground parts of vegetation are planted during the plants dormant period, usually October through April, but the months will vary in the US due to local climate. Another planting technique, the spreading of seeds, has not been very successful, and therefore, is not widely practiced as a principal planting technique.

Selection of plant types will vary for different locations and climates. The designer of the wetland should select five to seven plants that grow native to the area and design the depth zones in the wetland to be appropriate for the type of plant and its associated maximum water depth. Approximately half of the wetland should be planted. Of the five to seven species selected, three should be aggressive plants or those that become established quickly. Examples of aggressive species used in the Mid-Atlantic Region include softstem bulrush (*Scirpus validus*) and common three-square (*Scirpus americanus*). Aggressive plants as well as other native wetland plants are available from numerous nurseries. Most vendors require an advance order of 3 to 6 months.

After wetland excavation and grading the wetland should be inundated and allowed to stand until planting. Six to nine months later, the wetland is typically surveyed, drained, and staked. The wetland is surveyed two weeks prior to planting to ensure that depth zones are appropriate for plant growth. Revisions may be necessary to account for any depths different from that originally excavated. Staking the site ensures that the planting crew spaces the plants within the correct planting zone. Planting zones are used to avoid mixing species and creating competition within the planted areas. The State of Maryland recommends planting two aggressive or primary species in 4 monospecific areas and planting an additional 40 clumps (one or more individuals of a single species) per acre of each primary species over the rest of the wetland. Three secondary species are planted close to the edge of the wetland at an application rate of 10 clumps of 5 individual plants per acre of wetland, for a total of 50 individuals of each secondary species per acre of wetland. At least 48 hours prior to planting, the wetland should be drained. At the completion of planting and within 24 hours the wetland should be re-flooded.

The wetland design should include a buffer to separate the surrounding land uses from the wetland. Buffers may alleviate some of the potential nuisances associated with the wetland, such as accumulated floatables or odors. MWCOG recommends a buffer of 25 feet from the maximum water surface elevation, plus an additional 25 feet when wildlife habitat is of concern. An enhanced wildlife habitat can be obtained if during construction the removal of existing forested areas is minimized. If removal is necessary, the buffer area should be reforested. The reforestation also decreases the potential for a goose pond due to their preference for open areas.

MAINTENANCE

The use of wetlands for stormwater treatment is relatively new, and therefore, specific guidelines on their maintenance have not been established. The wetlands will require monitoring, reinforcement planting, sediment removal, and possibly plant harvesting. Access should be incorporated in the design to facilitate these maintenance activities. Monitoring the wetland during the first three years is crucial to the performance of the wetland. Inspections should be conducted twice per year for the first three years, and on an annual basis thereafter. Reinforcement planting may be required during this time period if the original plants do not flourish in the wetland. The inspector should determine sediment accumulation within the wetland and also take note of the species distribution/survival, water elevations, and outlet condition. Water elevations can be raised or lowered by adjusting the outlet's gate valve if it is determined that plants are not receiving an appropriate water supply. The forebay will likely require sediment clean-out every three to five years. The design of the forebay should allow for it to be drained so that a skid loader or backhoe can be used to remove the accumulated deposits (MWCOG, 1992). Mowing of the embankment and maintenance bench should occur twice per year. Other areas surrounding the wetland will not require mowing.

Numerous studies have been performed to determine the toxicity of pond sediments and whether landfilling or land application can be accomplished without having to meet hazardous waste requirements. Studies to date have not found sediments to be hazardous. Therefore, on-site land application of the sediments away from the shoreline will most likely be the most cost effective disposal method. On-site disposal is preferred over off-site disposal due to the cost savings associated with transportation and off-site disposal fees. Wetlands that receive flow from a drainage area containing industry and activities associated with hazardous waste may contain toxic levels in the sediments and testing may be required for these sediments prior to land application.

COSTS

Costs incurred for stormwater wetlands include those for permitting, design, construction and maintenance. The permitting costs vary depending on state and local regulations, but it has been estimated that permitting and design costs are between 15 and 25 percent of the construction cost. Construction costs for an emergent wetland range from $12,000 to $20,000 per acre of wetland and for a forested wetland range from $20,000 to $40,000 per acre of wetland. These costs include the costs for clearing and grubbing, erosion and sediment control, excavating, grading, staking, and planting. The cost for constructing the wetland is largely dependant upon the amount of excavation required at a site. Maintenance costs are estimated at 10 to 15 percent per year of the construction costs (Bowers, 1995).

ENVIRONMENTAL IMPACTS

Benefits associated with stormwater wetlands include increased downstream water quality, wetland creation, enhancement of wildlife habitat, and flood attenuation. Water quality is improved due to the partial removal of suspended solids, metals, nutrients, and bacteria. The creation of wetlands is typically looked upon as positive, particularly when the nation has lost considerable acres of wetlands within the past century. The wetlands provide an environment attractive to wildlife, such as sandpipers and herons. ED wetlands also attenuate runoff and alleviate downstream flooding.

Potential adverse impacts attributed with stormwater wetlands can occur upstream, in the wetland, and downstream of the wetland. There is potential for stormwater wetlands located in a large watershed (>100 acres) to experience degradation of upstream headwaters since they receive no effective hydrologic control (MWCOG, 1992). The wetland designer can incorporate upstream modifications to relieve this negative impact.

Concerns within the wetland are the potential for a fish barrier, habitation by undesirable species, and groundwater contamination. A fish barrier may be created by the wetland, which prohibits fish access to the full length of the stream. This may result in a lowering of fish diversity in the stream. Geese and mallards may become year round residents of the wetland if structural complexity is not included in the wetland design. Geese and mallards favor deep and open water areas. Forested buffer areas and a reduction of grassy areas will also deter the geese and mallards. The geese and mallards will increase the nutrient and coliform loadings to the wetland and will also likely be a nuisance to local residents. The issue of groundwater contamination resulting from migration of polluted sediments to the groundwater has been considered a potential negative environmental impact. However, studies to date indicate that there is little risk of groundwater contamination (MWCOG, 1992).

Stormwater wetlands can act as a heat sink, especially during the summer, and discharge warmer waters to downstream water bodies. The increased temperatures can negatively impact sensitive fish species and aquatic insects located downstream. Avoidance of the use of wetlands with temperature sensitive downstream species is recommended. Regardless of the sensitivity of downstream species, the designer should still take precautions in the design of wetlands to reduce the magnitude of warming in the wetland. The adverse impact can be minimized through careful design. Several possible remedies to each of the negative impacts (e.g., upstream degradation, stream warming, etc.) described are suggested in the publication *Design of Stormwater Wetland Systems* (MWCOG, 1992).

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STORM WATER BMP: VEGETATIVE COVERS

EPA MTB
Office of Wastewater Enforcement & Compliance
MUNICIPAL TECHNOLOGY BRANCH

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	Equipment	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.

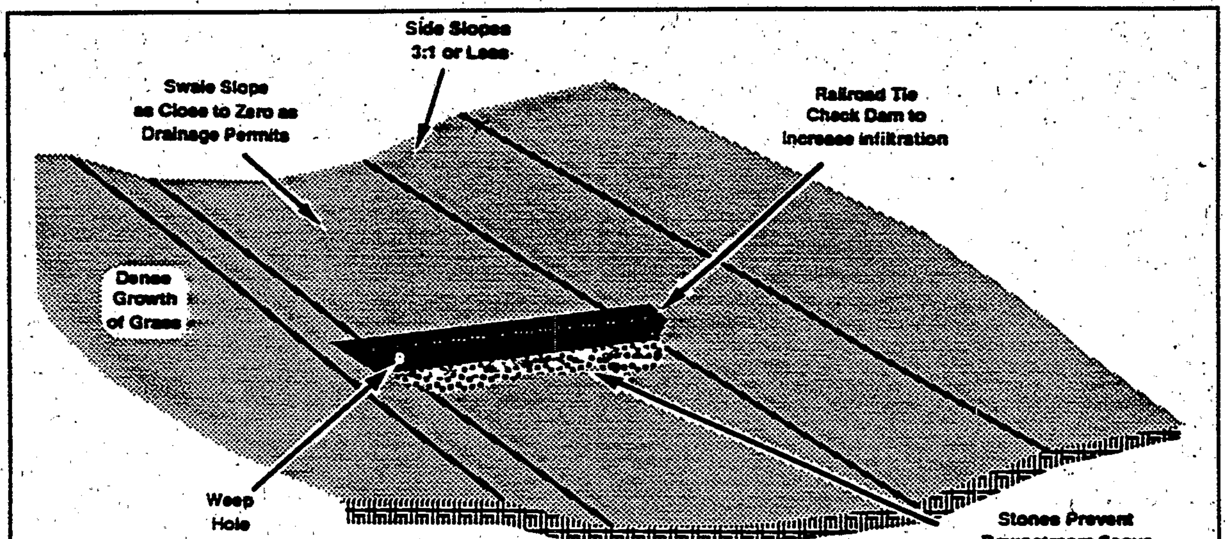
MTB
Office of Wastewater Enforcement & Compliance
MUNICIPAL TECHNOLOGY BRANCH

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.

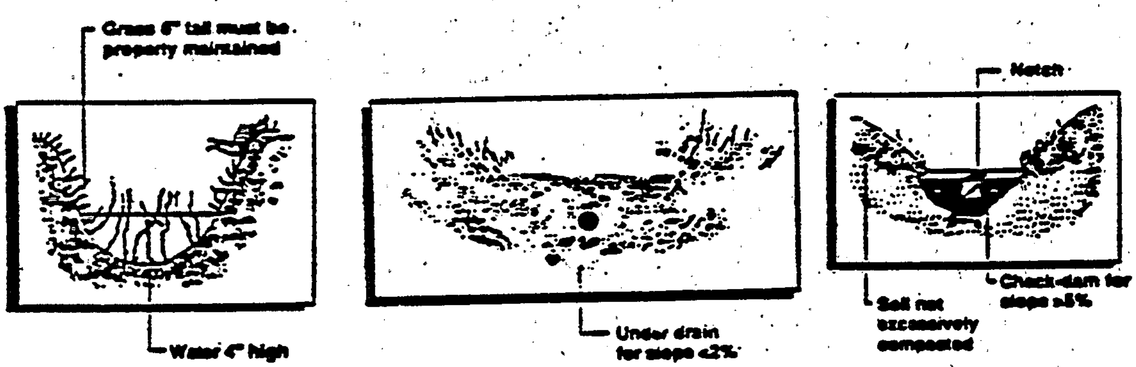
   - Slopes of less than 2 % can be used if the swale is drained to prevent ponding (Figure 2).

   - 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.

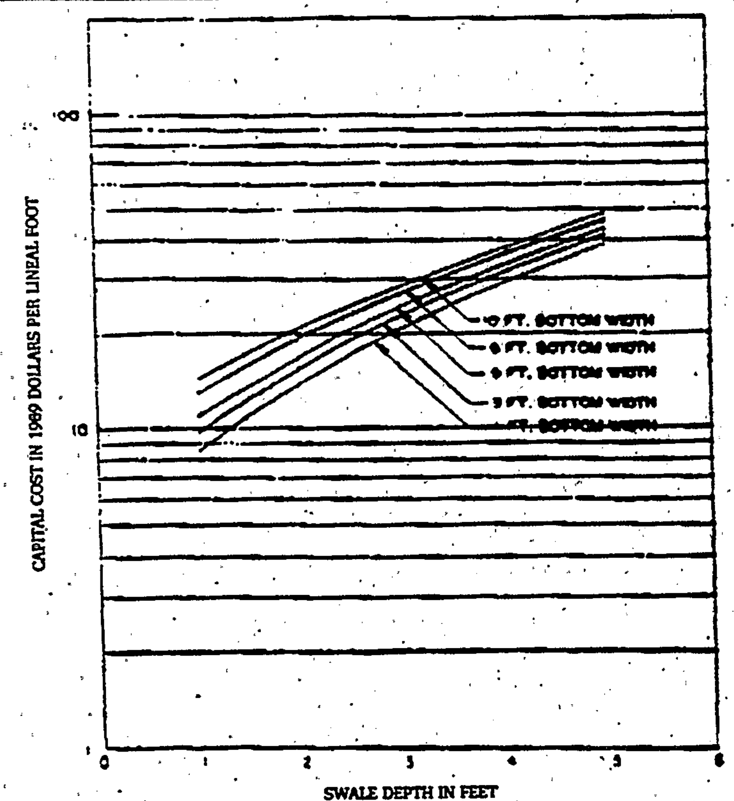
COSTS

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.

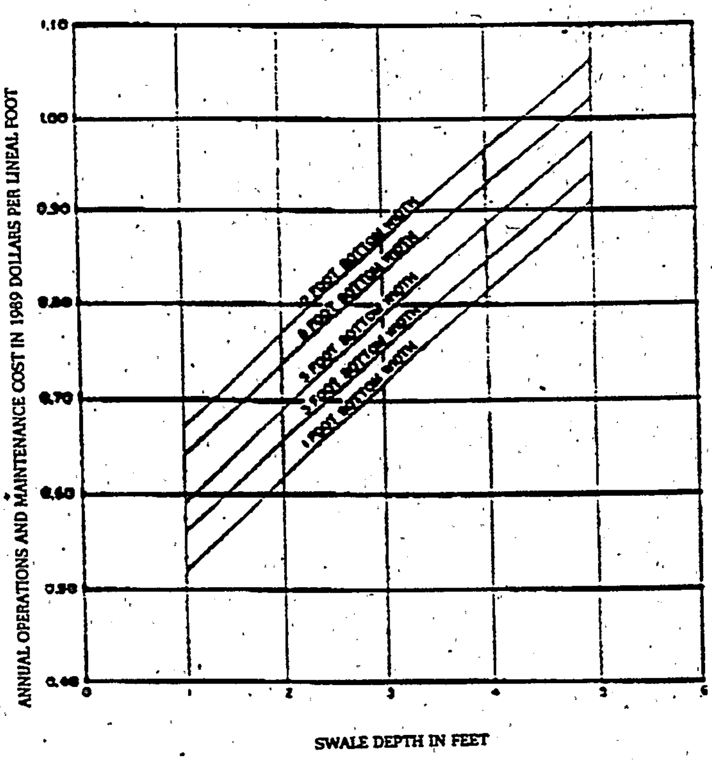
Annual costs associated with maintaining vegetated swales are approximately $0.58 per lineal foot for a 1.5-foot deep channel, according to SEWRPC (1991). Estimated average annual operating and maintenance costs of vegetated swales can be estimated using Table 2 below.

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.
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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.

REFERENCES

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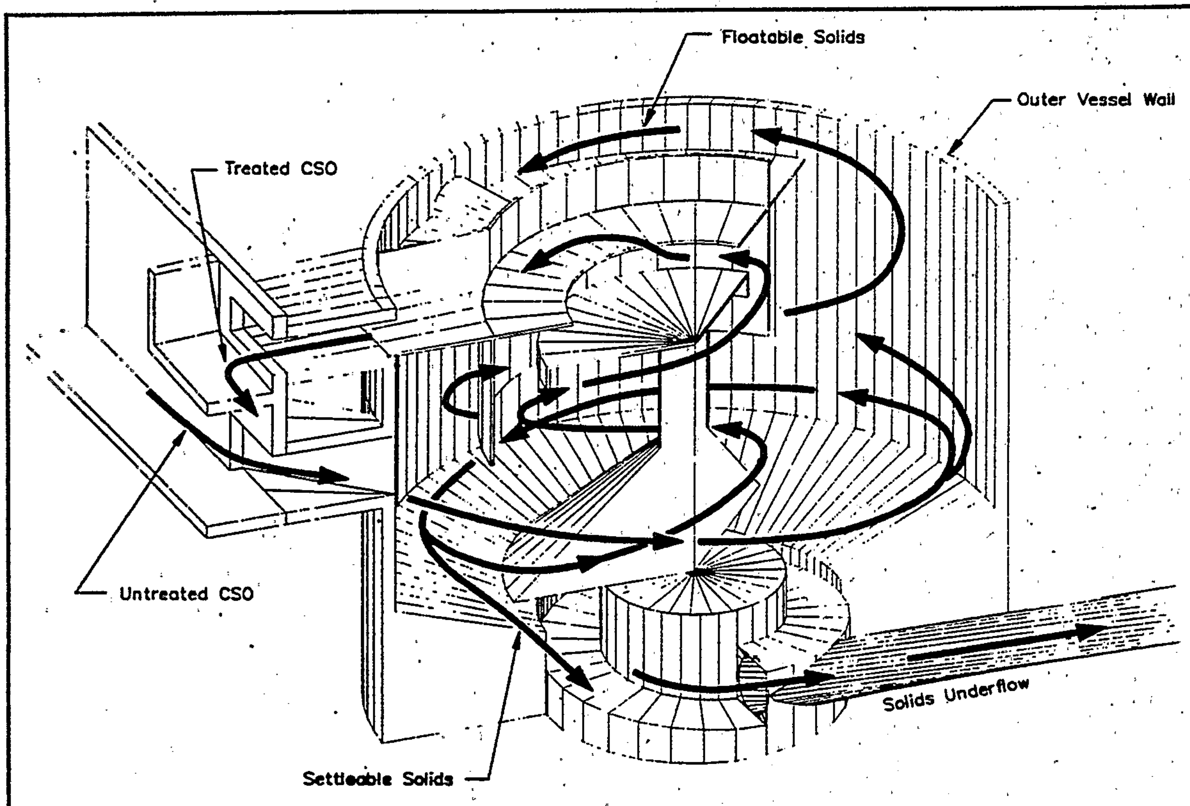
This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC 20460.

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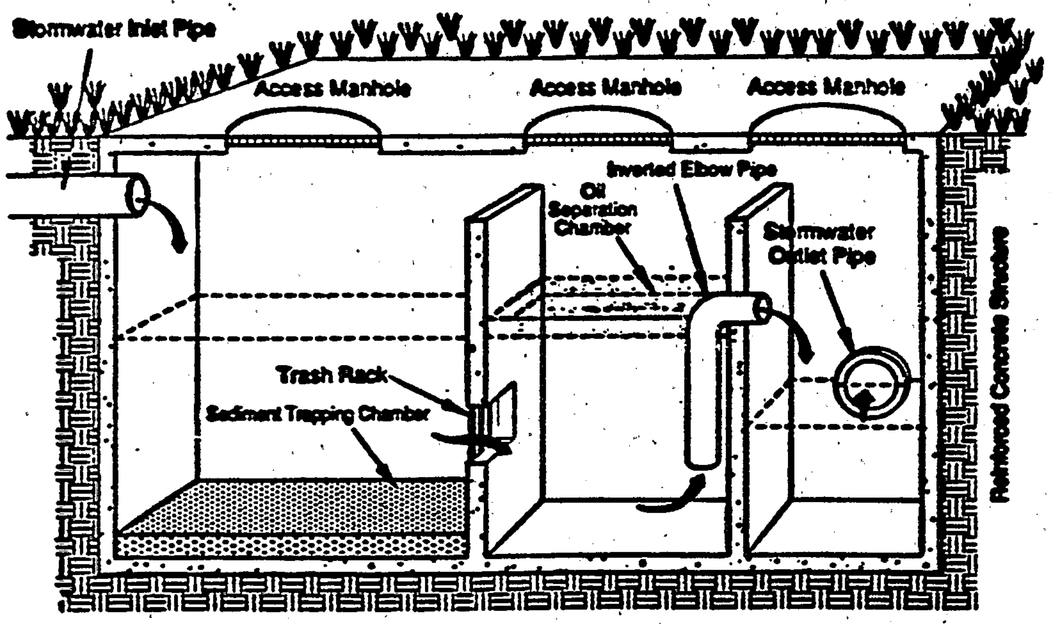
This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC, 20460

STORM WATER BMP: WATER QUALITY INLETS

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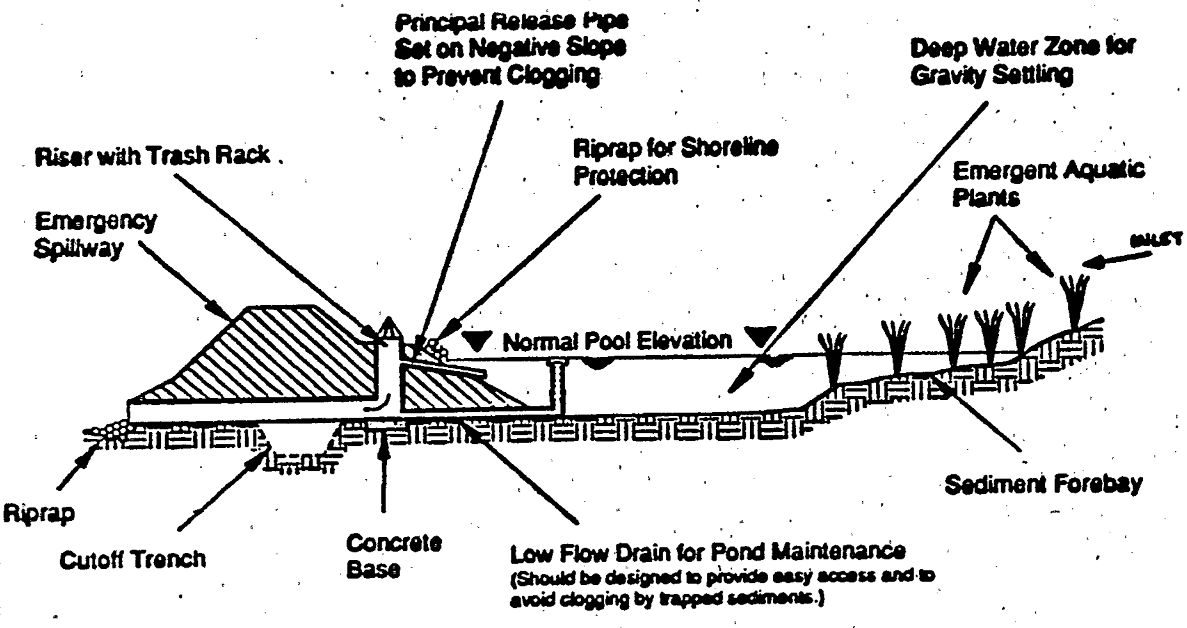
This BMP fact sheet was prepared by the Municipal Technology Branch (4204), US EPA, 401 M Street, SW, Washington, DC, 20460

STORM WATER BMP: WET DETENTION PONDS

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

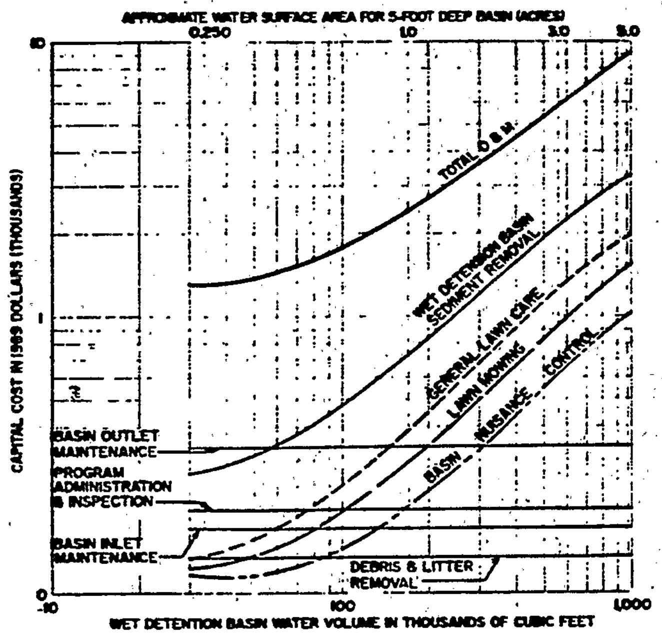
The total cost for a pond includes permitting, design and construction and maintenance costs. Permitting costs may vary depending on state and local regulations. Typically, wet detention ponds are less costly to construct in undeveloped areas than retrofitting into developed areas. This is due to the 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

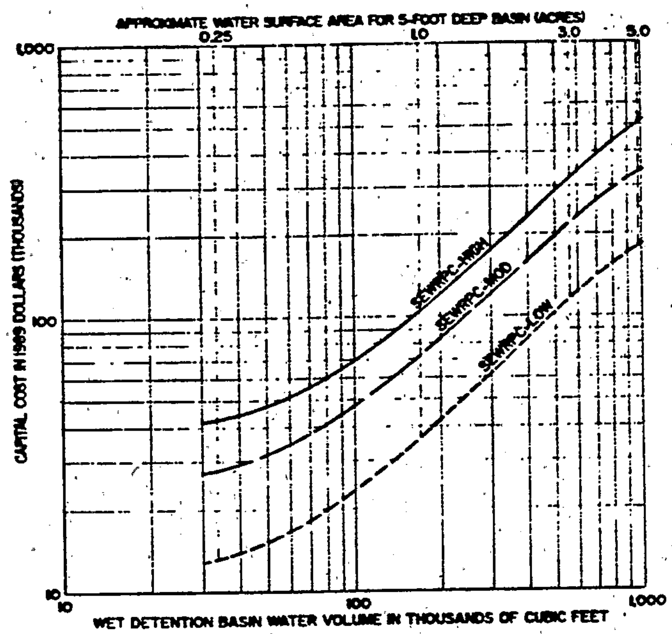
Wet detention ponds provide both storm water quantity and quality benefits. Benefits obtained from the use of wet detention ponds include decreased potential for downstream flooding and stream bank erosion. Water quality is also improved due to the removal of suspended solids, metals, and dissolved nutrients. 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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