ATTACHMENT

TO SUPPLEMENT "A" OF THE RIVERSIDE COUNTY DRAINAGE AREA MANAGEMENT PLANS

SELECTION AND DESIGN OF STORMWATER QUALITY CONTROLS

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I. INTRODUCTION

This manual outlines factors which planners and engineers need to consider when choosing and designing a structural best management practice (BMP) for a particular development site. It gives a brief overview of the different types of BMPs available and it identifies and presents specific BMPs that are applicable to Supplement "A".

Over the past two decades, a number of urban BMPs have been developed and refined to mitigate some of the adverse impacts associated with development activity. Experience has shown that each BMP option has both unique capabilities and persistent limitations. These, in turn, must be balanced with both the physical constraints imposed by the development site and the overall management objectives for the watershed. In practice, this balance is achieved through a negotiating process between the engineering consultant and the local development review staff. Typically, the consultant is responsible for developing the initial BMP plan, and represents the interests of the developer. The planner reviews the plan to ensure that it conforms with local policies and design standards, and represents the interests of the community. The goal is to develop a plan which represents both interests concurrently and equally.

It is important to note that runoff quality control is not yet a technical science. Rather, it is more an engineering art, with few design criteria for pollution removal having been established at this point. Therefore, it will be up to each jurisdiction to develop some performance standard for runoff control devices (with the program objective in mind). A credit system may be useful in evaluating the combined performance of the BMPs. The goal of any Municipal Stormwater Program is to reduce the discharge of pollutants to the maximum extent practicable (MEP), the Environmental Protection Agency's (EPA) measure for compliance. Although not specifically defined in the Federal regulations, the intent of MEP is to reduce the discharge of pollutants as much as possible. To accomplish this, many factors including technical feasibility and effectiveness as well as economic factors must be taken into consideration.

II. URBAN BEST MANAGEMENT PRACTICES

The term BMP, or Best Management Practice, has gained wide acceptance as a general term designating any method for controlling the quantity and quality of stormwater runoff. Urban BMPs are generally grouped into four categories based on the operating principle or physical mechanism used to reduce the amount of runoff pollutants discharged to surface waters. These include:

> DETENTION BASINS - The term "detention" applies when the runoff is temporarily stored and, apart from relatively minor incidental losses due to evaporation or percolation, is subsequently discharged to surface water. Control results from a reduction in pollutant concentrations due to settling during the period the runoff is detained.
>
> RETENTION DEVICES - The term "retention" applies when runoff is permanently captured so that it never discharges directly to a surface water. The usual mechanism by which stormwater controls permanently "capture" surface runoff is by infiltration. These techniques are often referred to as infiltration BMPs.

VEGETATIVE CONTROLS - Vegetative controls provide contact between stormwater runoff and vegetated areas and accomplish pollutant removal by a combination of filtration, sedimentation and biological uptake that reduce pollutant concentrations, and/or by a reduction in runoff volume due to infiltration or evapo-transpiration. Figure 1 provides a schematic illustration of various types of vegetative BMPs.

SOURCE CONTROLS - Source control techniques include any practice that either (1) reduces the amounts of accumulated pollutants on the land surface available for washoff by rainfall, (2) regulates the amount of impervious area to reduce the portion of rainfall that will appear as runoff, or (3) excludes inappropriate discharges to storm drains.

Source controls are generally difficult to implement because the sources are diffuse, coming from streets, parking lots, rooftops, lawns, cars, atmospheric rainfall, and so forth. Treatment is equally difficult because of the hydrologic variability and the dilute concentration of the waste stream being treated. But much can be done to improve the quality of the stormwater that runs off our urban developments if the designer is simply cognizant of possibilities for and desirous of maximizing the water quality.

In general, source controls are preferable to structural or treatment controls because they minimize pollution and are less expensive to implement and maintain. However, a coordinated effort to implement both is necessary to achieve the desired/required level of runoff quality control. As in any new program, it is important to evaluate needs and constraints at the beginning of the process to ensure that the best controls are selected. Table 1 gives a brief overview and compares the effectiveness of a number of these currently used BMPs.

FIGURE 1: Vegetative BMPs take many forms and are used for various purposes.
Adapted from Schueler, 1987.

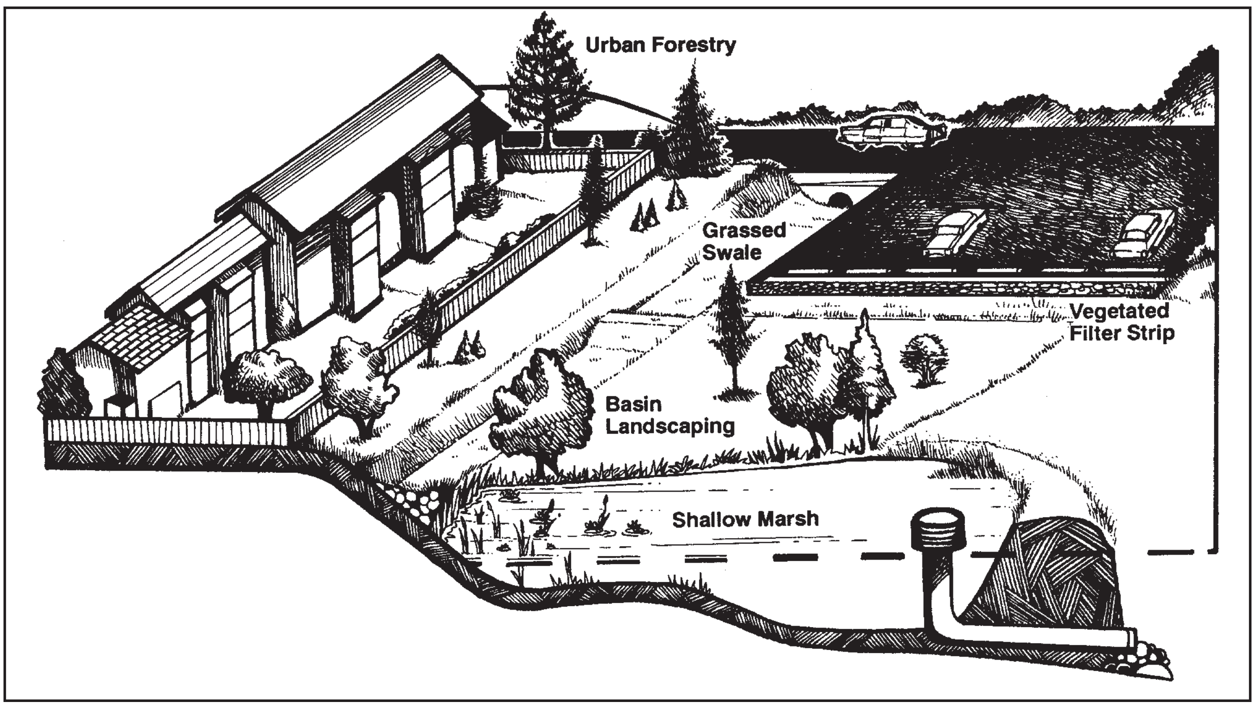


Table 1. A COMPARATIVE ASSESMENT OF THE EFFECTIVENESS OF CURRENT URBAN BEST MANAGEMENT PRACTICES

URBAN BMP OPTIONS*	RELIABILITY FOR POLLUTANT REMOVAL	LONGEVITY*	APPLICABLE TO MOST DEVELOPMENTS	WILDLIFE HABITAT POTENTIAL	ENVIRONMENTAL CONCERNS	COMPARATIVE COST	SPECIAL CONSIDERATIONS
INFILTRATION TRENCHES	Presumed Moderate	50% Failure rate within 5 years	Highly restricted (soils, groundwater, slope, area, sediment input)	Low	Slight risk of groundwater contamination	Cost-effective on smaller sites; rehab costs can be considerable	Recommended with pretreatment and geotechnical evaluation
INFILTRATION BASINS	Presumed moderate, if working	60-100% failure within 5 years	Highly restricted (see infiltration trench)	Low to moderate	Slight risk of groundwater contamination	Construction cost moderate, but rehab cost high	Not widely recommended until longevity is improved
POROUS PAVEMENT	High (if working)	75% failure within 5 years	Extremely restricted (traffic, soils, groundwater, slope, area, sediment input)	Low	Possible groundwater contamination	Cost effective compared to conventional asphalt when working properly	Recommended in highly restricted application with careful construction and effective maintenance
SAND FILTERS	Moderate to high	20+ years	Applicable for smaller developments	Low	Minor	Comparatively high construction costs and frequent maintenance	Recommended, with local demonstration
GRASSED SWALES	Low to moderate but unreliable	20+ years	Low-density development and roads	Low	Minor	Low compared to curb and gutter	Recommended, with checkdams as one element of a BMP system
FILTER STRIPS	Unreliable in urban settings	Unknown, but may be limited	Restricted to low-density areas	Moderate if forested	Minor	Low	Recomended as one element of a BMP system
WATER QUALITY INLETS	Presumed low	20+ years	Small, highly impervious catchments (<2 acres)	Low	Resuspension of hydrocarbon loadings; disposal of hydrocarbo and toxic residuals	High, compared to trenches and sand filters	Not currently recommended as a primary BMP option

* Based on current designs and prevailing maintenance practices. Source: Metropolitan Washington Council of Governments, 1992

III. CHOOSING THE BEST BMP FOR THE SITE

There is no generic method by which these different control techniques can be ranked either qualitatively or quantitatively. Site specific conditions determine which practices are best, and even whether a particular approach is appropriate. At a minimum, the BMP plan jointly developed for a site should accomplish the following goals:

1. Be appropriate for the site, given physical constraints
2. Reproduce pre-development hydrological conditions
3. Provide moderate pollutant removal capability
4. Have neutral impact on the environment
5. Be cost effective and
6. Have acceptable future maintenance burden

To aid the planner or engineer in selecting the most appropriate BMP for a particular development site, a series of screening tools have been developed to compare the capabilities and limitations of each BMP. The screening tools can be used in any order, or may be used as an overall summary of BMP performance. Key factors that influence the suitability of a particular BMP include the following:

* ***Drainage area served*** - The feasibility of a particular control measure depends on the drainage area. There tends to be an upper and/or lower bounds of the urban drainage area that can be served with a particular control practice. These bounds are based on design features and size requirements, as well as the operation characteristics of the BMP. Figure 2 presents a number of BMPs and the associated range of feasible drainage areas.

* ***Soil permeability*** - The soil type, which effectively governs the long term percolation rate, is an important feature which can limit the applicability of a technique at a site. Figure 3 illustrates typical ranges of infiltration rates associated with different soil types and their impact on the feasibility of different BMPs.

* ***Other site factors*** - Other common physical restrictions on BMPs include slope, high water table, distance to bedrock, proximity to foundations and wells, land consumption, maximum depth, restricted land uses, high sediment input, and thermal enhancement. Table 2 represents a matrix that shows whether a BMP is subject to these restrictions.

* ***Environmental amenities*** - In most cases, environmental amenities are not automatically provided when a BMP is built. Rather, they are a result of thoughtful design, regular maintenance, and creative landscape planting. Table 2 shows the environmental and human amenities which can be provided by a particular BMP. The first five headings refer to amenities related to the improvement of the natural environment, while the last five headings pertain to amenities which are provided to the adjacent community. As community amenities are quite subjective, some generalities have been made.

* ***Stormwater benefits*** - The objective of stormwater management is to attempt to reproduce the pre-development hydrology of the site. Table 2 shows the extent to which common BMP designs provide these benefits. Studies have shown that capturing or treating the first ¼ to ½ inch of runoff (small frequent storms with 1 to 2 month return period) will result in 80 to 95 percent capture of the runoff volume; however, before developing detention criteria for a given geographical area, local rainfall analyses should be performed.

* ***Pollutant removal*** - The pollutant removal capability of a BMP is primarily governed by three interrelated factors: 1) the removal mechanisms; 2) the fraction of the annual runoff volume that is effectively treated; and 3) the nature of the urban pollutant being treated. Figure 4 illustrates the comparative pollutant removal capabilities of BMP options. The design variations for each BMP are arrayed in order of increasing fractions of annual runoff volume treated.

* ***Maintenance and cost*** - A final step in selecting a control method is estimating the cost by taking into account all factors associated with the method. Construction and both short and long term maintenance are the major cost components.

Consideration of the components discussed above will usually permit a planner to significantly reduce the choice of control practices appropriate for a detailed evaluation. An explanation of the individual screening factors is presented in Appendix A.

A comprehensive approach to stormwater management views stormwater as a resource and sees the land as a treatment medium. Stormwater management should replenish groundwater supplies, maintain the dry weather flow of urban streams through infiltration and delayed discharge, reduce stream warming, use vegetation to utilize water pollutants as fertilizer, and reduce flooding.

IV. DESIGN CONSIDERATIONS

Once a BMP has been selected for the site, more detailed design of the facility can begin. The following section describes several variations in the basic design of selected BMPs. These designs illustrate innovative ways to fit a BMP into a particular development site and combine BMPs together to improve performance or minimize maintenance needs. Each section concludes with a brief design summary that highlights some of the recommended BMP design features that should be included in every site plan. Both the engineering consultant and the site-plan reviewer can use these summaries as a checklist to ensure that the BMP plan for the site will be effective.

Key design features of the different control techniques are identified, but it should be recognized that other variations are possible. Appropriate studies and reports should be reviewed for additional detail on design, installation and operating aspects of specific BMPs. A list of selected references and other resources is provided at the end of this manual for further evaluation.

FIGURE 2: Feasible BMPs for different watershed sizes. ***Source: Schueler, 1987.***

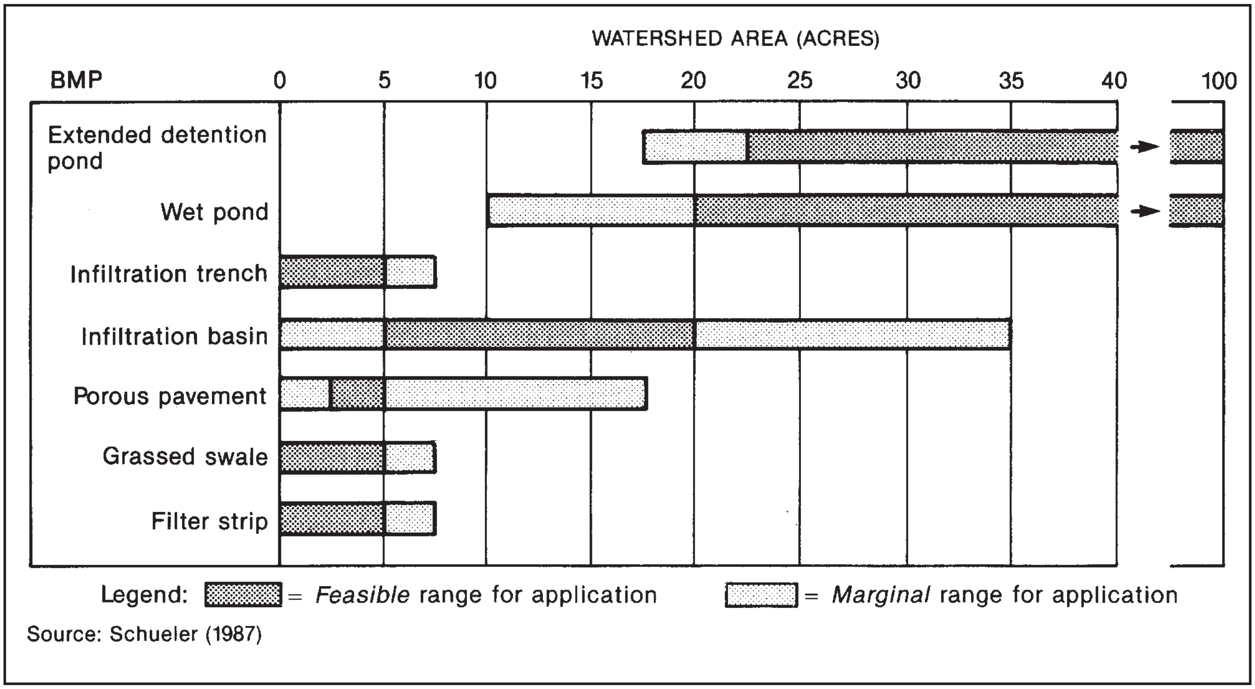


FIGURE 3: Restrictions for BMP application based on soil permeability. ***Source: Schueler, 1987.***

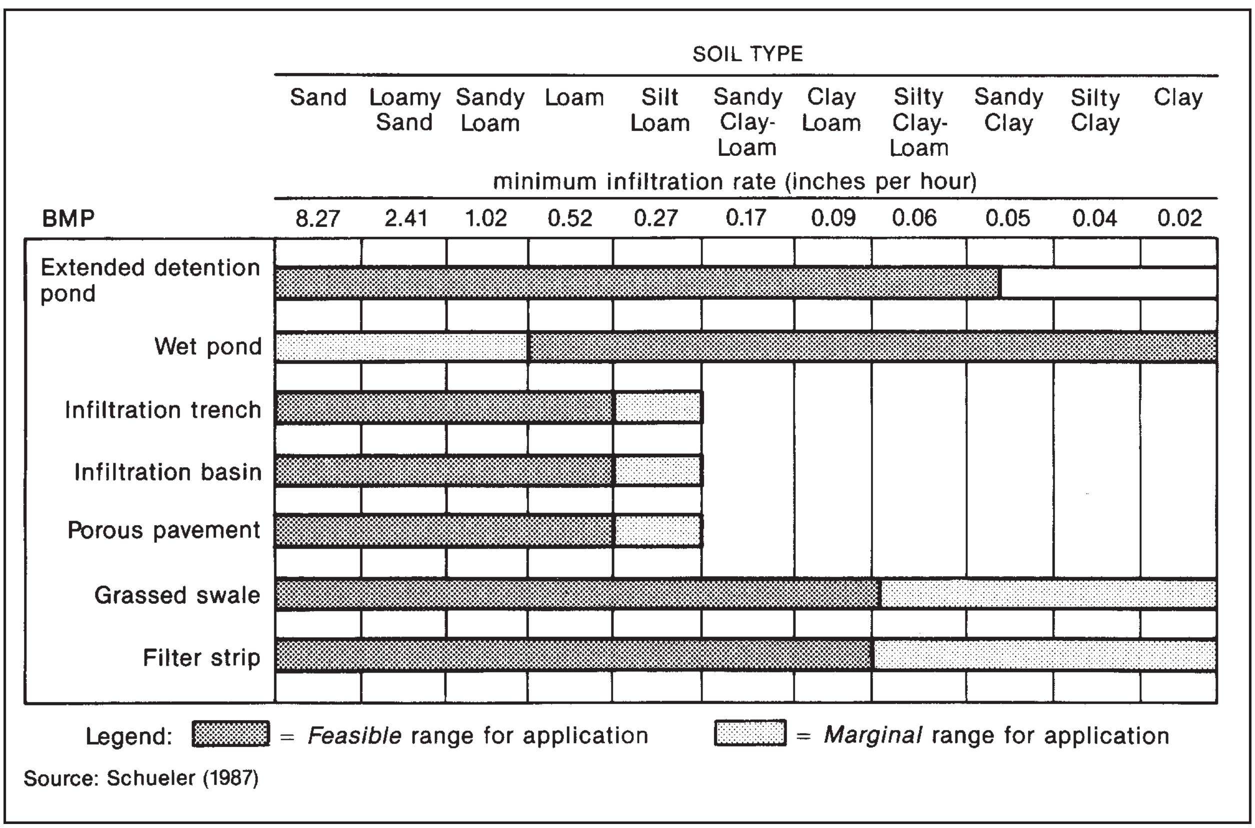


Table 2. COMPARATIVE BENEFITS PROVIDED BY URBAN BMPs. Source: Metropolitan Washington Council of Governments. 1993

FACTORS		INFILTRATION TRENCH	INFILTRATION BASIN	POROUS PAVEMENT	GRASSED SWALE	FILTER STRIP	WATER QUALITY INLET
SITE	Slope	X	O	X	X	O	
	High Water Table	X	X	X	X	O	
	Close to Bedrock	X	X	X	O	O	X
	Proximity to Foundations	X	O	X	O	O	X
	Space Consumption		O	X			
	Maximum Depth	X	X	X			X
	Restricted Land Uses			X	X	O	X
	High Sediment Input	X	X	X	X	X	X
	Wetlands/Forest Permits						
	Stream Warming						
ENVIRONMENT AND COMMUNITY	Low flow maintenance				O	O	X
	Streambank erosion control	O	O	O	X	X	X
	Aquatic Habitat Creation	X	X	X	X	X	X
	Wildlife Habitat Creation	X		X	O		X
	No Thermal Enhancement						
	Landscape Enhancement	X	O	X	O	O	X
	Recreational Benefits	X	O	X	X	X	X
	Hazard Reduction						
	Aesthetics	X	X	X	O	O	X
	Community Acceptance		O				
STORMWATER	2 Year Storm				O	O	X
	10 Year Storm	O	O	O	X	X	X
	100 Year Storm	X	O	O	X	X	X
	Volume Control				O	O	X
	Groundwater Recharge				O	O	X
	Streambank Erosion Control		O	O	X	X	X

X Seldom provided (May preclude the use of a BMP)
O Sometimes provided (Can be overcome w/careful site design)
BLANK Ussually provided (Generally not a restriction)

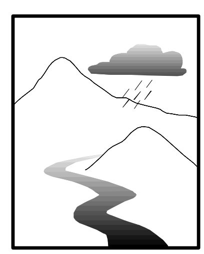
FIGURE 4: Comparative Pollutant Removal Of Urban BMP Designs

BMP/design	Suspended Sediment	Total Phosphorus	Total Nitrogen	Oxygen Demand	Trace Metals	Bacteria	Overall Removal Capability
EXTENDED DETENTION POND							
DESIGN 1	◕	◔	◔	◔	◑	⊗	MODERATE
DESIGN 2	●	◑	◔	◑	◕	⊗	MODERATE
DESIGN 3	●	◕	◑	◑	◕	⊗	HIGH
WET POND							
DESIGN 4	◕	◑	◔	◔	◔	⊗	MODERATE
DESIGN 5	◕	◑	◔	◔	◕	⊗	MODERATE
DESIGN 6	●	◕	◑	◑	◕	⊗	HIGH
INFILTRATION TRENCH							
DESIGN 7	◕	◑	◑	◕	◕	◕	MODERATE
DESIGN 8	●	◑	◑	◕	●	◕	HIGH
DESIGN 9	●	◕	◕	●	●	●	HIGH
INFILTRATION BASIN							
DESIGN 7	◕	◑	◑	◕	◑	◕	MODERATE
DESIGN 8	●	◑	◑	◕	●	◕	HIGH
DESIGN 9	●	◕	◕	●	●	●	HIGH
POROUS PAVEMENT							
DESIGN 7	◑	◕	◑	◕	◑	◕	MODERATE
DESIGN 8	●	◕	◕	◕	●	●	HIGH
DESIGN 9	●	◕	◕	●	●	●	HIGH
WATER QUALITY INLET							
DESIGN 10	○	⊗	⊗	⊗	⊗	⊗	LOW
FILTER STRIP							
DESIGN 11	◔	○	○	○	◔	⊗	LOW
DESIGN 12	●	◑	◑	◕	●	⊗	MODERATE
GRASSED SWALE							
DESIGN 13	○	○	○	○	○	⊗	LOW
DESIGN 14	◔	◔	◔	◔	○	⊗	LOW

KEY:

- ○ 0 TO 20% REMOVAL
- ◔ 20 TO 40% REMOVAL
- ◑ 40 TO 60% REMOVAL
- ◕ 60 TO 80% REMOVAL
- ● 80 TO 100% REMOVAL
- ⊗ INSUFFICIENT KNOWLEDGE

Design 1: First-flush runoff volume detained for 6-12 hours.
Design 2: Runoff volume produced by 1.0 inch, detained 24 hours.
Design 3: As in Design 2, but with shallow marsh in bottom stage.
Design 4: Permanent pool equal to 0.5 inch storage per impervious acre.
Design 5: Permanent pool equal to 2.5 (Vr); where Vr=mean storm runoff.
Design 6: Permanent pool equal to 4.0 (Vr); approx. 2 weeks retention.
Design 7: Facility exfiltrates first-flush; 0.5 inch runoff/imper. acre.
Design 8: Facility exfiltrates one inch runoff volume per imper. acre.
Design 9: Facility exfiltrates all runoff, up to the 2 year design storm.
Design 10: 400 cubic feet wet storage per impervious acre.
Design 11: 20 foot wide turf strip.
Design 12: 100 foot wide forested strip, with level spreader.
Design 13: High slope swales, with no check dams.
Design 14: Low gradient swales with check dams.

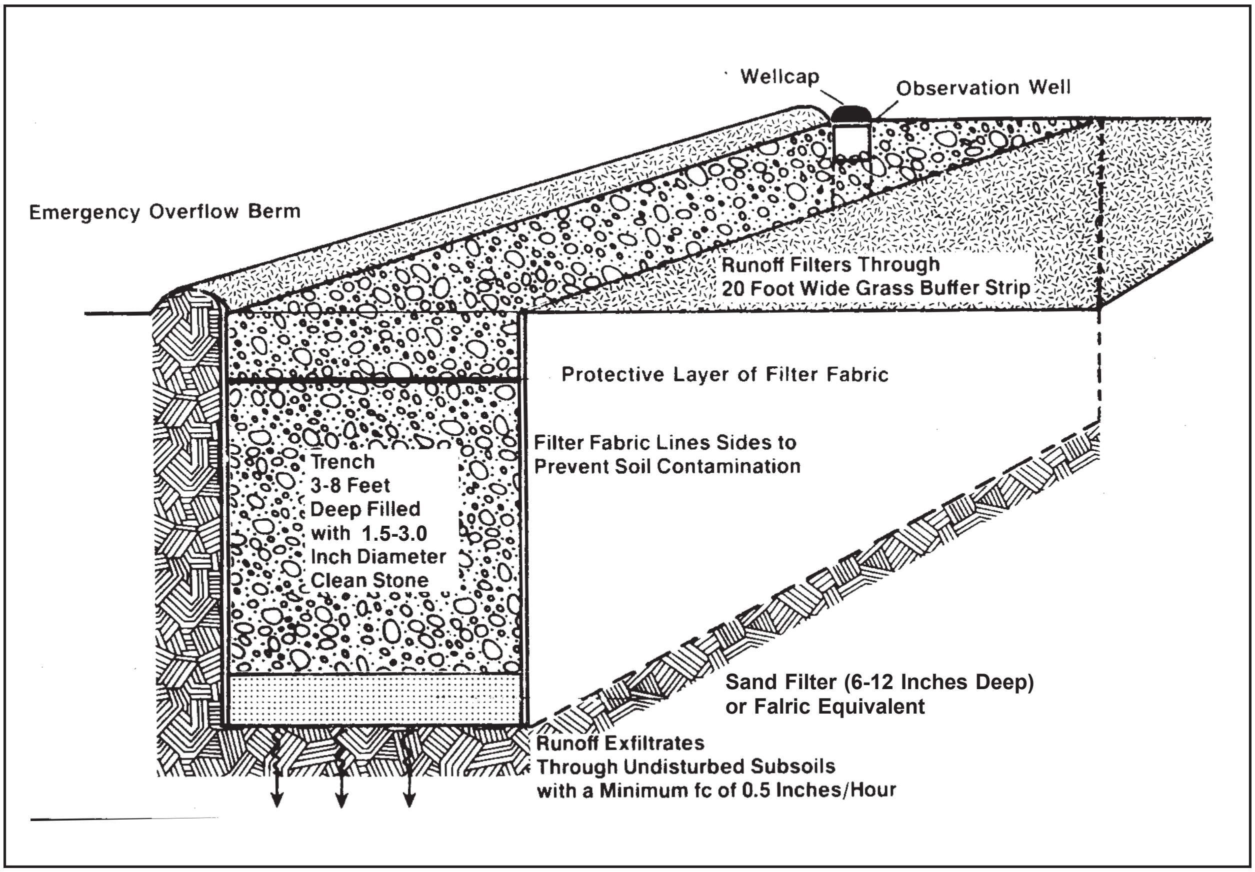


SECTION V

INFILTRATION TRENCHES

Infiltration trenches are an adaptable BMP that effectively remove both soluble and particulate pollutants. As with other infiltration systems, trenches are not intended to trap coarse sediments. Grass buffers (for surface trenches) or special inlets (for underground trenches) must be installed to capture sediment before it enters the trench. Depending on the degree of storage/exfiltration achieved, trenches can provide groundwater recharge, low flow augmentation and localized streambank erosion control. Individual trenches are primarily an on-site control, and are seldom practical or economical on sites larger than 5 or 10 acres. Trenches are only feasible when soils are permeable and the water table and bedrock are situated well below the bottom of the trench. Aside from regular inspections and more rigorous sediment and erosion control, trenches have limited routine maintenance requirements. However, trenches will prematurely clog if sediment is not kept out before, during and after construction of a site. If a trench does become severely clogged, partial or complete replacement of the structures may be required.

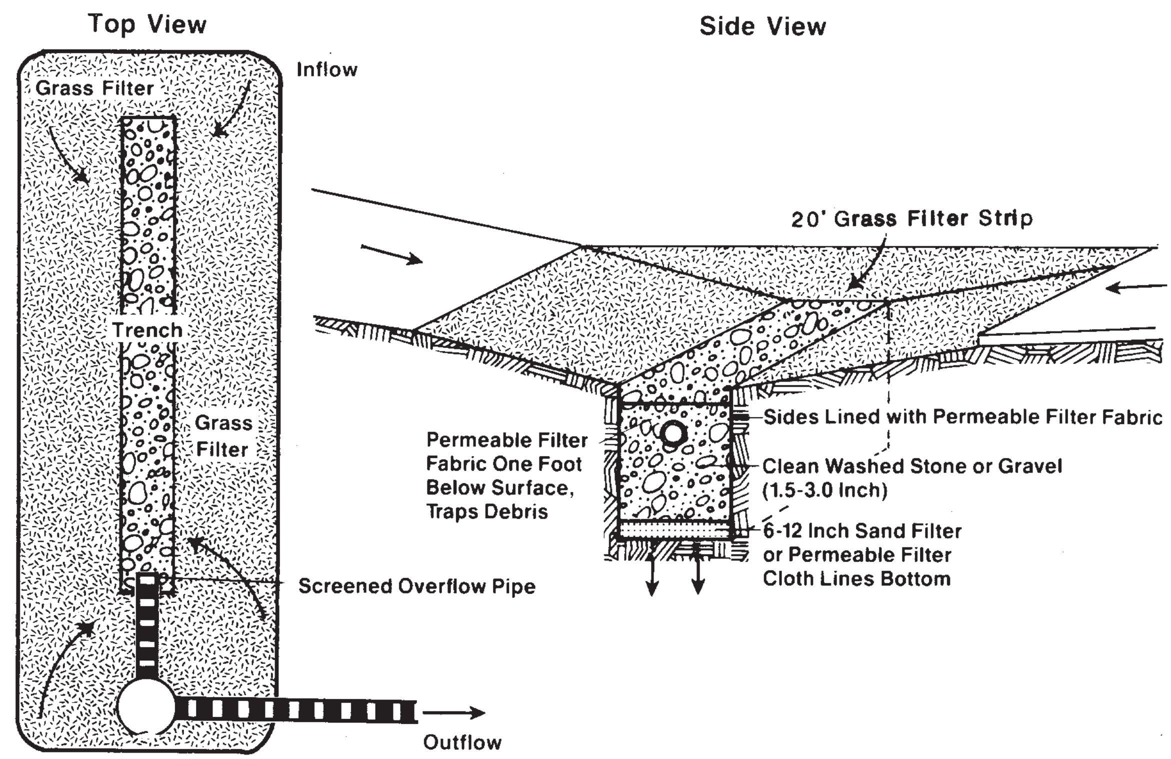
FIGURE 1: Schematic of an Infiltration Trench



DESIGN 1:

Median Strip Design (Figure 2). This design is frequently used for highway median strips and parking lot "islands" (depressions in between two lots or adjacent sides of one lot). Sheet flow is accepted from both sides of the trench, and is filtered through a 20-foot wide grassed buffer strip. The strip is an integral part of the trench, and should be graded to have a uniform slope not greater than 5%, and should directly abut the contributing impervious area. Berms located on each side of the strip form a shallow depression that temporarily store runoff before it enters the trench. An overflow pipe is used to pass excess runoff.

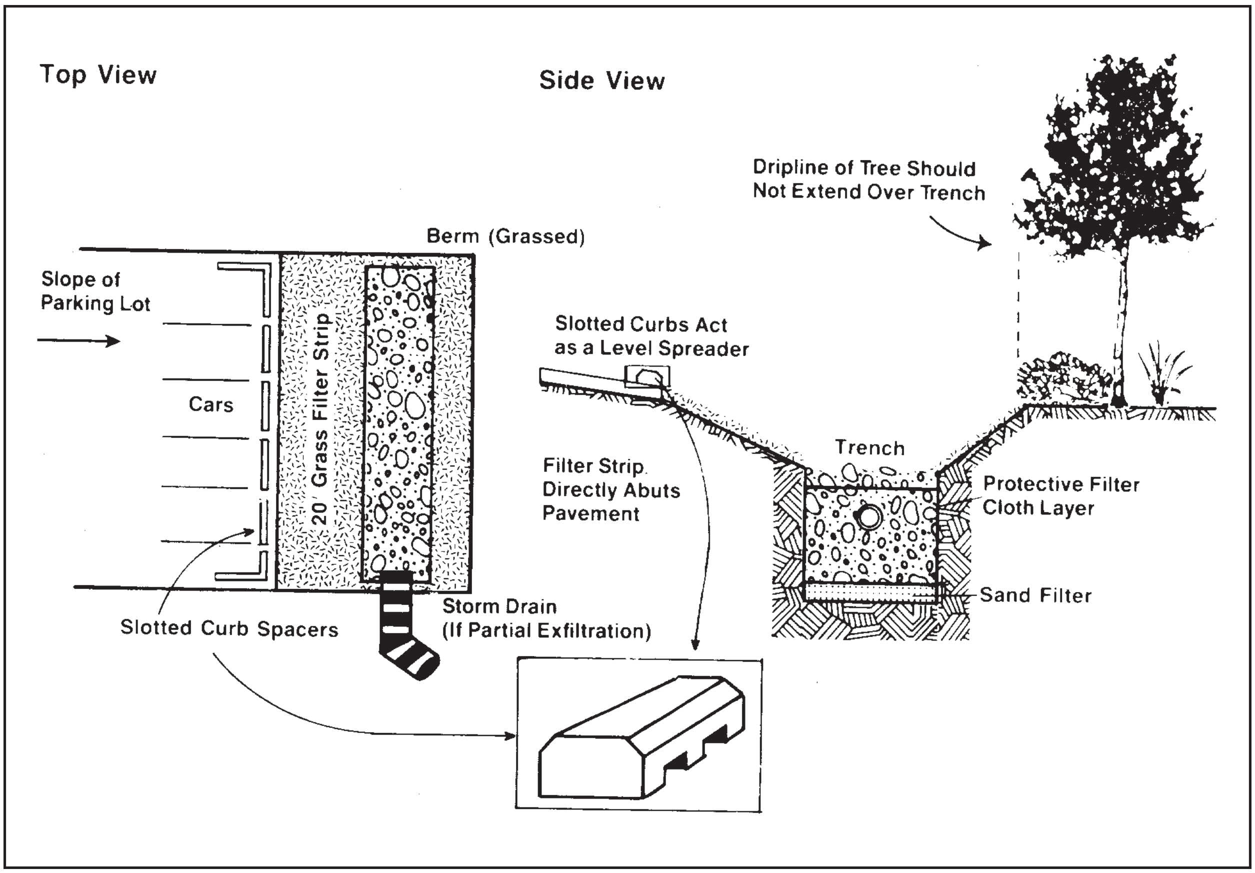
FIGURE 2: Median Strip Trench Design



DESIGN 2:

Parking Lot Perimeter (Figure 3). This design accepts sheet flow from the lower end of a parking lot. Slotted curb spacers are used as level spreaders to route sheet flow from the parking lot over the 20-foot wide filter strip (and also keep cars from damaging the strip). After being filtered over the grass strip, runoff enters the surface of the trench. A shallow berm is installed at the far end of the trench to ensure that runoff does not escape. The trench should have an overflow to pass large design storms, such as a PVC pipe with holes drilled on its underside, set near the top of the trench.

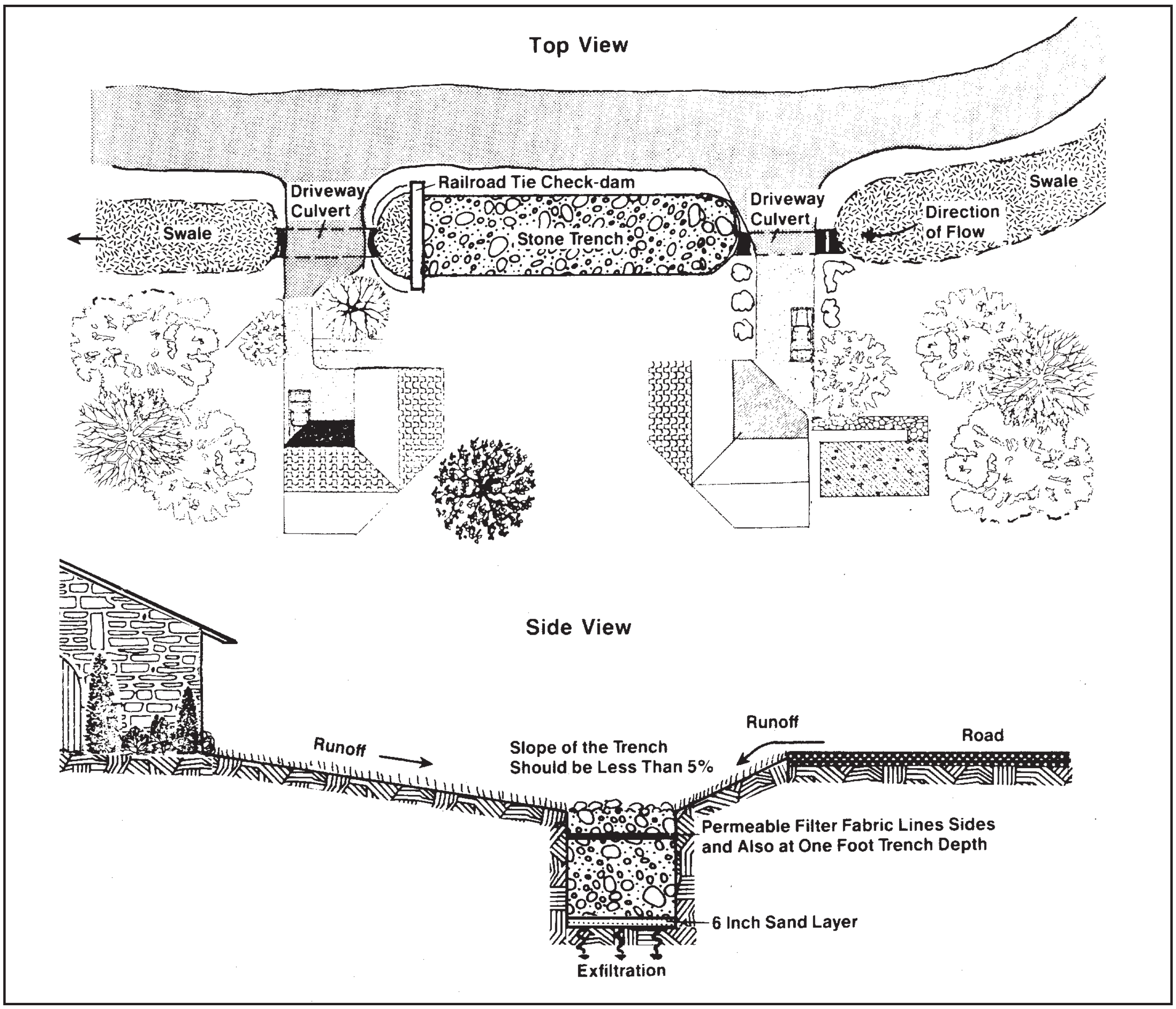
FIGURE 3: Parking Lot Perimeter Trench Design



DESIGN 3:

Swale Designs (Figure 4). Low density residential runoff (5-15% impervious) can be treated through a series of surface trenches located in swale drainage systems. The major design requirement is that the longitudinal slope of the swale collection system should never exceed 5%. Otherwise, concentrated flows will develop that might erode the swales and contaminate the trench. In addition, concentrated flows may pass around or over the surface of the trench and never infiltrate. An earthen check dam or railroad tie placed perpendicularly to the flow path, on the downstream side of the trench, can prevent "short-circuiting" and increase the volume of runoff exfiltrated by the trench. The slope of the trench should be as close to zero as feasible, and should have sideslopes of 5:1 (h:v) or less.

FIGURE 4: Swale/Trench Design



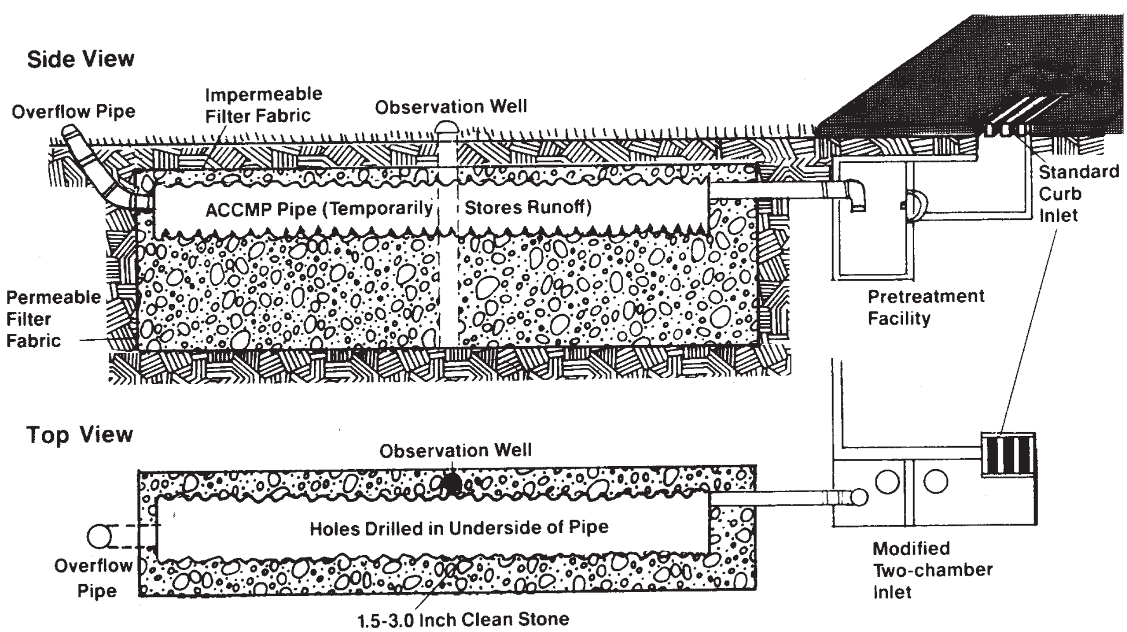
UNDERGROUND TRENCH APPLICATIONS

Underground trenches can be applied in a variety of development situations, and are particularly suited to accept concentrated runoff. However, it is important to pretreat concentrated runoff before it enters underground trenches, and to evenly distribute it within the trench. The top of the trench is protected by a layer of impermeable geo-textile, and is covered by topsoil and planted with grass. While the aesthetics of underground trenches may be better than surface trenches, maintenance can be more difficult and costly (particularly, if the trench must be covered by pavement or concrete). Often "out-of-sight" means "out-of-mind". Consequently, underground trenches should only be installed when strong, enforceable maintenance agreements can be secured from the property owner.

DESIGN 1:

Oversized Pipe Trench (Figure 5). In some designs, an oversized corrugated metal pipe is placed within the trench. Holes are drilled through the pipe to allow runoff to drain to the stone reservoir and then into the subsoil. The oversized pipe is protected from clogging by a layer of filter fabric. The primary advantage of this approach is that it increases the available temporary storage of the trench (i.e., more void space is provided within the pipe than if it was occupied by stone aggregate). The feasibility of the oversized pipe approach is governed by the exfiltration rate of the subsoil, as the pipe must completely drain within 72 hours. As with other underground trench designs, runoff must be pretreated. A two-chamber inlet design is shown in Figure 5.

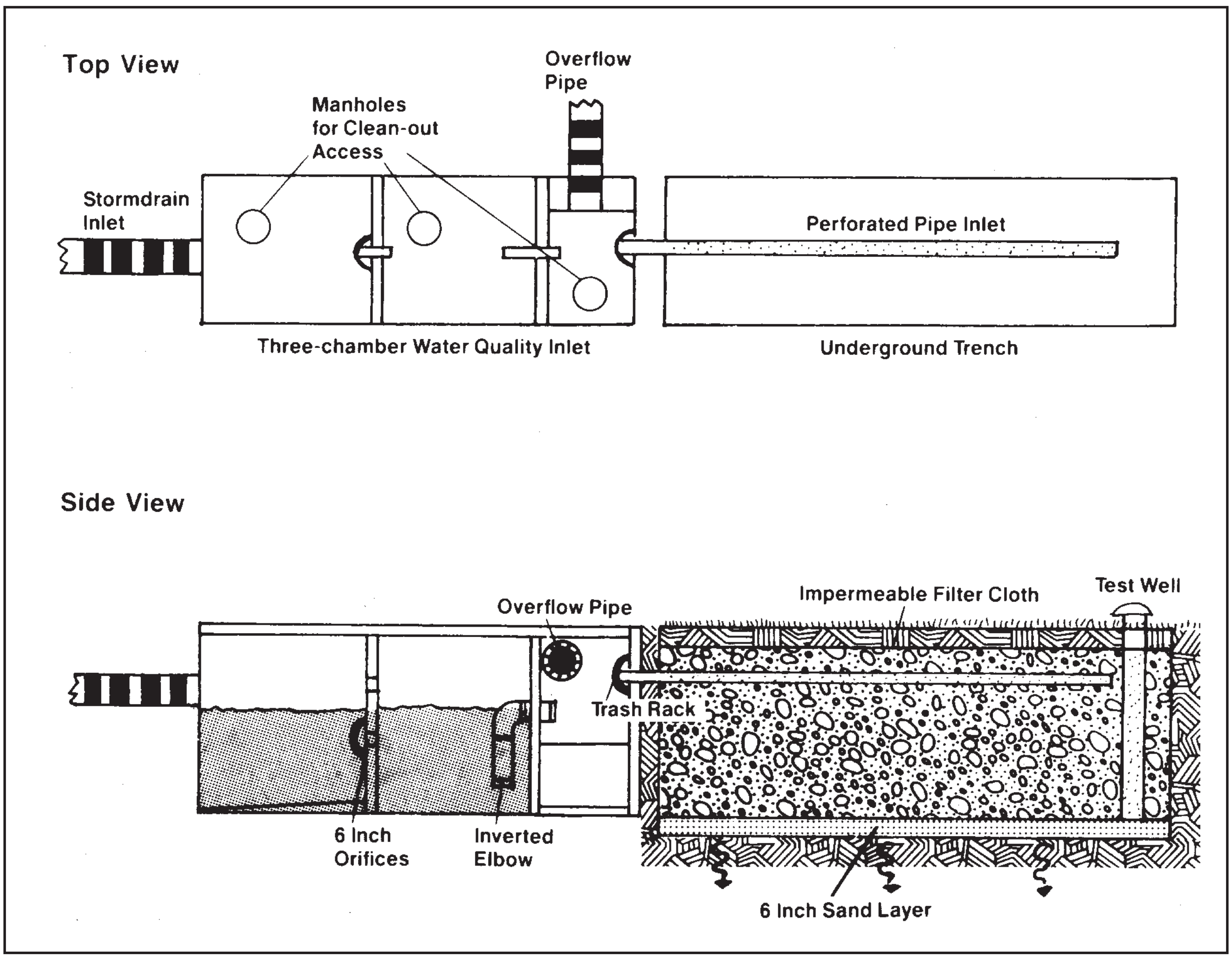
FIGURE 5: Oversized Pipe Trench Design



DESIGN 2:

Underground Trench with Oil/Grit Inlet (Figure 6). Commercial/ industrial parking lots produce significant loads of grit and oil that can and do rapidly clog the top of surface trenches, and also provide greater stormwater flows that must be collected by a storm drain. In those development situations, an oil/grit inlet may be used to pretreat the runoff before it enters the trench. Three chamber designs are popular, whereby the first chamber traps coarse sediment and litter, the second chamber separates out the oil and grease, and the third chamber serves as the inlet to the trench. If the trench is desired for either partial or water quality exfiltration, the third chamber must also have the capability to divert overflow to a storm drain network (see Water Quality Inlets section for more information). A perforated pipe extends along the top of the underground trench so the runoff can be evenly distributed across the stone reservoir.

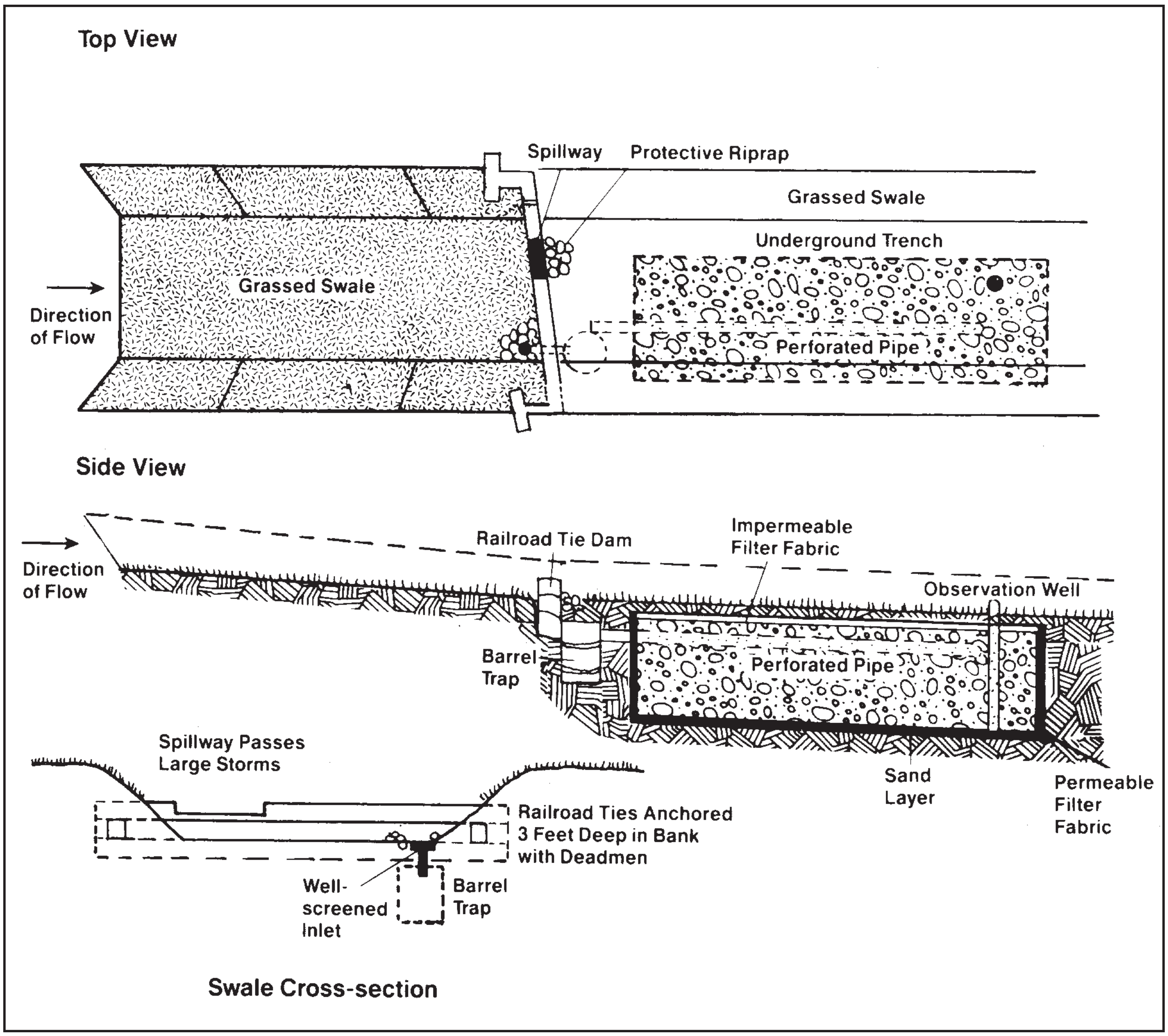
FIGURE 6: Underground Trench with Oil/Grit Chamber



DESIGN 3:

Under-the-Swale Design (Figure 7). A surface trench located in a swale may not always be a popular choice for nearby residents. An alternative approach is to place a railroad tie weir across the swale, drop a barrel inlet at the base of the weir to trap sediment, and extend a perforated pipe from the barrel and along the top surface of the trench to distribute runoff evenly. The top of the trench is then covered by at least two layers of nearly impermeable geo-textile, with a 6 to 12 inch layer of topsoil placed on top. After grass is established, only the test well and railroad tie weir will be visible to residents.

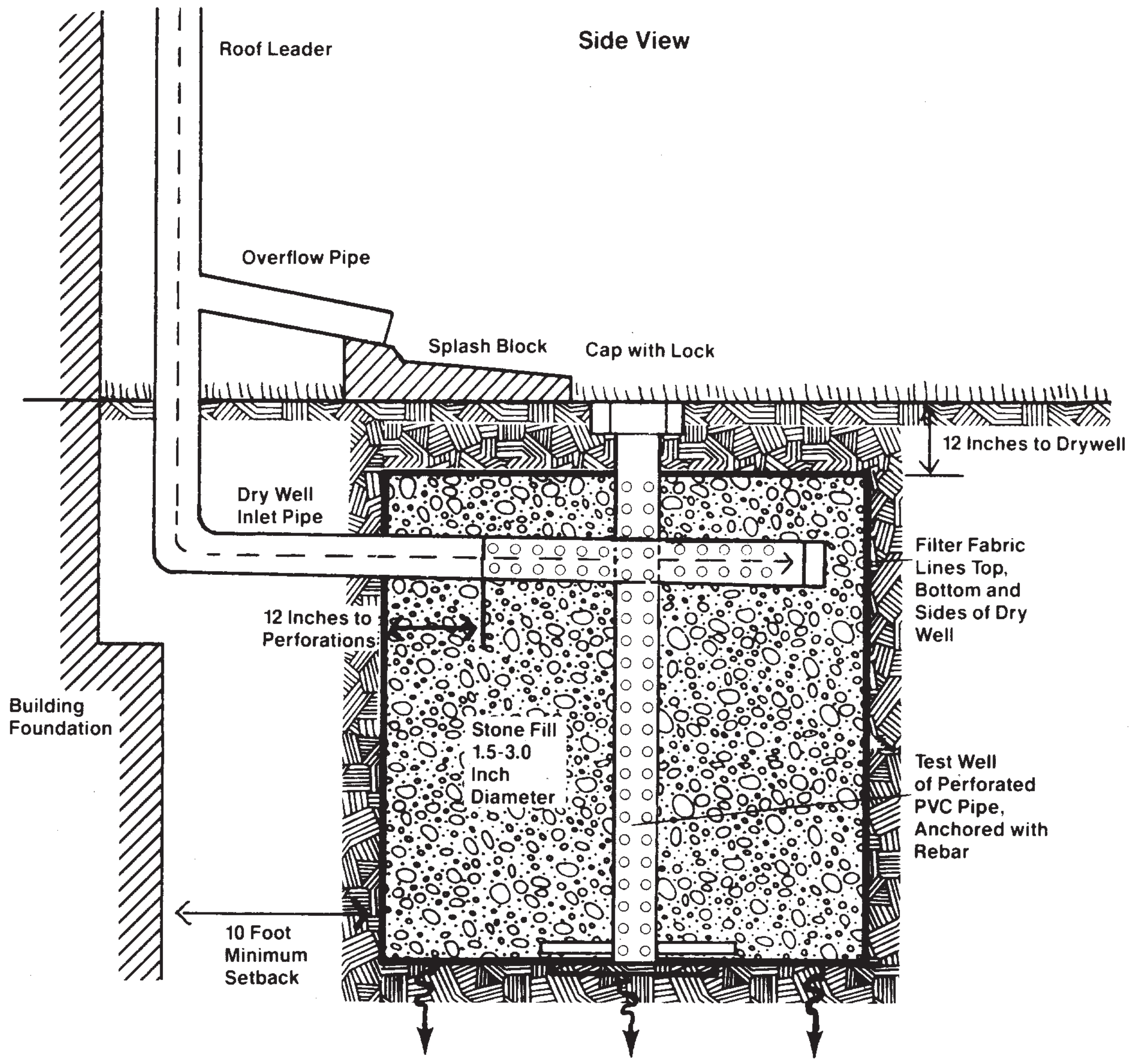
FIGURE 7: Under-the-Swale Trench Design



DESIGN 4:

Dry Well Designs (Figure 8). Dry wells are a basic trench variation which are designed exclusively to accept rooftop runoff from residential or commercial buildings. Additional guidance on dry well design is available from Md WRA (1984). Basically, the leader from the roof is extended into an underground trench, which is situated a minimum of ten feet away from the building foundation. Rooftop gutter screens are needed to trap any particles, leaves and other debris, and must be regularly cleared.

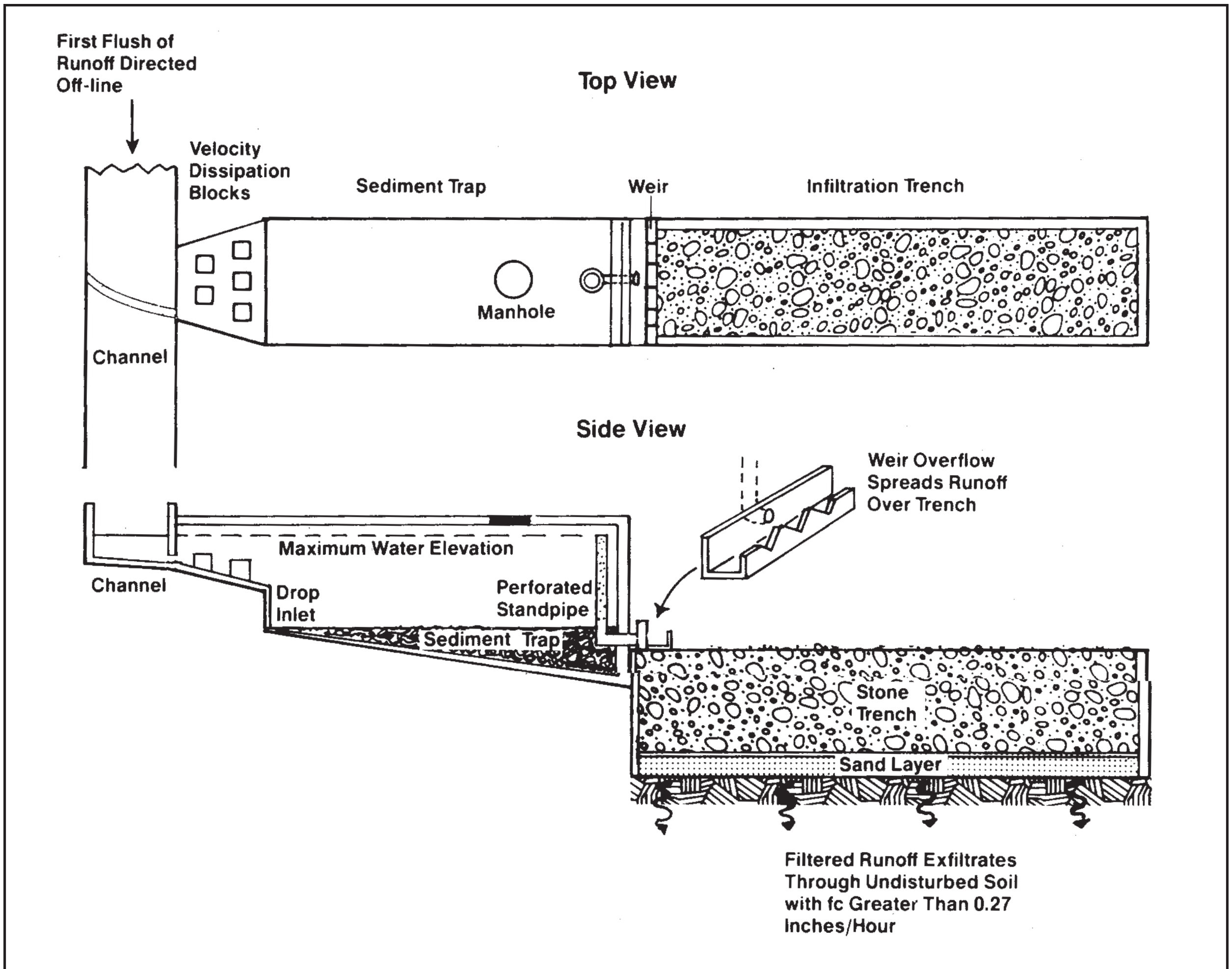
FIGURE 8: Dry Well Design (Adapted from Md WRA, 1986)



DESIGN 5:

Off-Line Trench System Designs (Figure 9). Several designs have been originated in Texas (Austin DPW, 1986) that utilize a combination of off-line sediment traps, sand filters and infiltration trenches to treat the first flush of runoff. In one design, a weir is placed across a natural or man-made channel that diverts runoff into an off-line sediment trap. After sediment drops out, the runoff enters a vertical perforated pipe that drains to a level-spreading weir. Runoff then passes over a sand filter to remove any fine particulates or grease remaining in the runoff. After percolating through the sand filter and a layer of permeable filter fabric, runoff is stored in a gravel or stone reservoir, and then exfiltrated into the subsoil (alternatively, runoff from the gravel or stone reservoir can be collected by an underdrain network and be returned to the stream). Some general sizing rules for the area of the sediment trap and trench surface area adapted from Austin DPW (1986) are shown in Figure 9.

FIGURE 9: Off-line Trench System Design



DESIGN SUMMARY: INFILTRATION TRENCHES

- **SITE ELEVATION**:
  Soils must be tested prior to design to determine whether infiltration is feasible for a site. Soil borings should be taken to a depth at least five feet below the anticipated bottom of the trench to check for soil infiltration capability, depth to seasonally high water table, and bedrock level. The minimum field infiltration rate (fc) of the underlying soils should be greater than 0.27 inches/hour.

- **WATERSHED SIZE**:
  The watershed area contributing to each trench should not exceed 5 acres.

- **DEGREE OF EXFILTRATION**:
  To achieve significant pollutant removal, at least ½ inch of runoff per contributing impervious acre should be exfiltrated into the underlying soils. A more efficient design will accommodate the runoff produced from a 1 inch storm over the contributing watershed.

- **CONSTRUCTION**:
  All trenches should be excavated using light equipment, taking care not to compact the underlying soils used for exfiltration. The sides of the trench should be lined with filter fabric to prevent the entry of sediment into the trench. A 6-inch layer of sand or filter fabric should be used to line the bottom of the trench. Clean, washed stone aggregate, 1.5 to 3.0 inches in diameter, should be used for fill, although wash pea-gravel may be an unacceptable alternate in some cases.

- **PRETREATMENT OF RUNOFF**:
  To prevent premature clogging of trenches, sediment, grit, and oil must be removed by a pre-treatment facility before they enter a trench. For surface tenches, a minimum 20-foot wide grass buffer is required as a filter. In addition, a layer of filter fabric placed 1 foot below the surface of the trench can be used to trap sediments that get through the grass buffer. Pretreatment technologies for underground trenches include barrel inlets, water quality inlets, and modified catch basins.

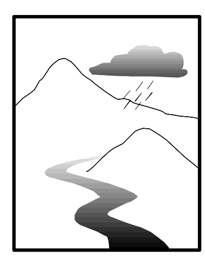
- **MAXIMUM DRAINING TIME:**
  All trenches should be designed to completely drain within 72 hours after the design exfiltration event. This enables the underlying soils to dry out (improving pollutant removal capability) and frees up storage capacity for the next storm. On sites with soils of marginal infiltration capacity (silt loams, loams), it may be advisable to design trenches to drain within 48 hours. This is done by maximizing the surface area of the trench floor, or reducing the depth of the trench, or both.

- **MINIMUM DRAINING TIME:**
  Partial exfiltration trenches should be designed so that all available storage space in the trench is filled before runoff is collected by the underdrain and routed out of the facility. This can be done by installing a perforated pipe (with holes drilled through the bottom) near the top of the trench to collect excess runoff. Perforated underdrains situated at the bottom of the trench may become too efficient at collecting runoff, and thus reduce pollutant removal.

- **OBSERVATION WELLS:**
  An observation well, consisting of a well-anchored vertical perforated PVC pipe, should be installed in every trench to monitor its performance. The well should be checked several times within the first few months after construction, by recording trench water depth at 0, 24 and 48 hours after a storm. The clearance rate of runoff (inches/hour) in the trench can be calculated by dividing the drop in water level (inches) by the time elapsed (hours) from the end of the storm. A measurement of trench clearance rate should be taken during each annual maintenance inspection. A series of such measurements over the years provides an excellent means of tracking any clogging within the trench.

- **EROSION CONTROL:**
  Trenches should not be constructed until the entire upland contributing area has been stabilized (i.e., after construction is completed). The planned area for the trench should be roped off to prevent compaction by heavy equipment. During construction, sediment and erosion controls such a diversion berms, for example, should be used to keep sediment and runoff completely away from the trench site.

- **ANNUAL MAINTENANCE:**
  A legally enforceable and binding maintenance agreement should be included in the property deed for each trench that clearly spells out maintenance tasks and schedules. Annual public sector inspections should be conducted to check on the performance of the trench and the required maintenance tasks. These include maintaining a dense grass buffer strip for surface trenches, removing accumulated sediments within the pre-treatment devices of underground trenches, and partially or totally reconstructing the trench in the event of clogging.



SECTION V

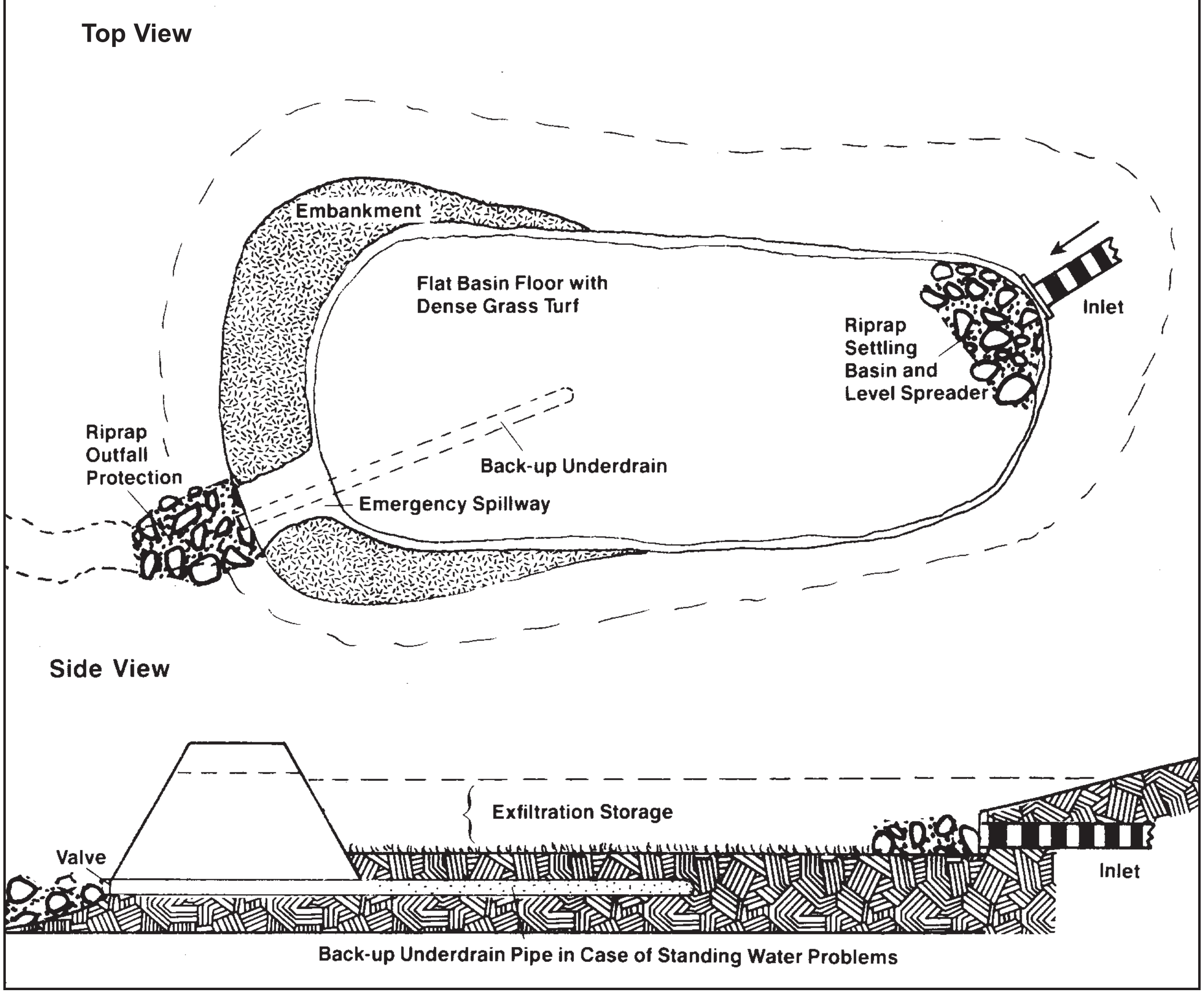
INFILTRATION BASINS

Infiltration basins are effective in removing both soluble and fine particulate pollutants borne in urban runoff. Coarse-grained pollutants should generally be removed before they enter a basin. Unlike other infiltration systems, basins can be easily adapted to provide full control of peak discharges for large design storms. Also, basins can serve relatively large drainage areas (up to 50 acres). Depending on the degree of storage/exfiltration achieved in the basin, significant groundwater recharge, low flow augmentation and localized streambank erosion control can be achieved.

FIGURE 1: Schematic of an Infiltration Basin

NOTE:

1. **Backup underdrain is not used in most applications because plugging occurs in soil above the drain.**
2. **An infiltration basin can also be excavated (typically 2 to 6 feet deep) as long as the bottom of the basin is 3 feet above high seasonal water table.**



Basins are a feasible option where soils are permeable and the water table and bedrock are situated well below the soil surface. Both the construction costs and maintenance requirements for basins are similar to those for conventional dry ponds. Infiltration basins do need to be inspected regularly to check for standing water. Experience to date has indicated that infiltration basins have one of the higher failure rates of any BMP.

Advantages of infiltration basins are that they preserve the natural water balance of the site, can serve larger developments, can be used as sediment basins during the construction phase, and are reasonably cost effective in comparison with other BMPs. Disadvantages of infiltration basins include a fairly high rate of failure due to unsuitable soils, the need for frequent maintenance, possible nuisances (e.g., odors, mosquitos, soggy ground), and some practical design problems.

INFILTRATION BASIN DESIGNS

A schematic of an infiltration basin is shown in Figure 1. The appearance and construction of infiltration basins is similar in many respects to conventional dry ponds. An impoundment is forced by excavation or by constructing an embankment. The impoundment stores a defined quantity of runoff, allowing it to slowly exfiltrate through the permeable soils of the basin floor. The floor is graded as flat as possible and a dense turf of grass is established to promote infiltration and bind up deposited sediments. Additional storage can be provided in the basin for temporary detention of the larger runoff volumes associated with the two year and/or ten year design storm, utilizing a conventional riser. An emergency spillway is used to pass runoff volumes in excess of the design storm controlled.

While simple in concept, infiltration basins do present some practical problems from a design standpoint. Problems emerge because infiltration methods are not very good at handling the concentrated flows and sediment loads that are generated from larger watersheds. Thus, basin design must incorporate measures that:

1. Trap excess loads of coarse grained sediment before they enter the basin and clog the surface soil pores on the basin floor.

2. Route design storm flows through the basin without scouring or eroding the basin floor.

3. Route base flow (if any exists) rapidly through the basin to prevent ponding or standing water.

4. Distribute storm runoff volume evenly over the floor of the basin to maximize exfiltration rates.

5. Provide a backup drainage system should the infiltration capacity of the basin fail.

Some variations in infiltration basin design that address these problems are discussed ahead.

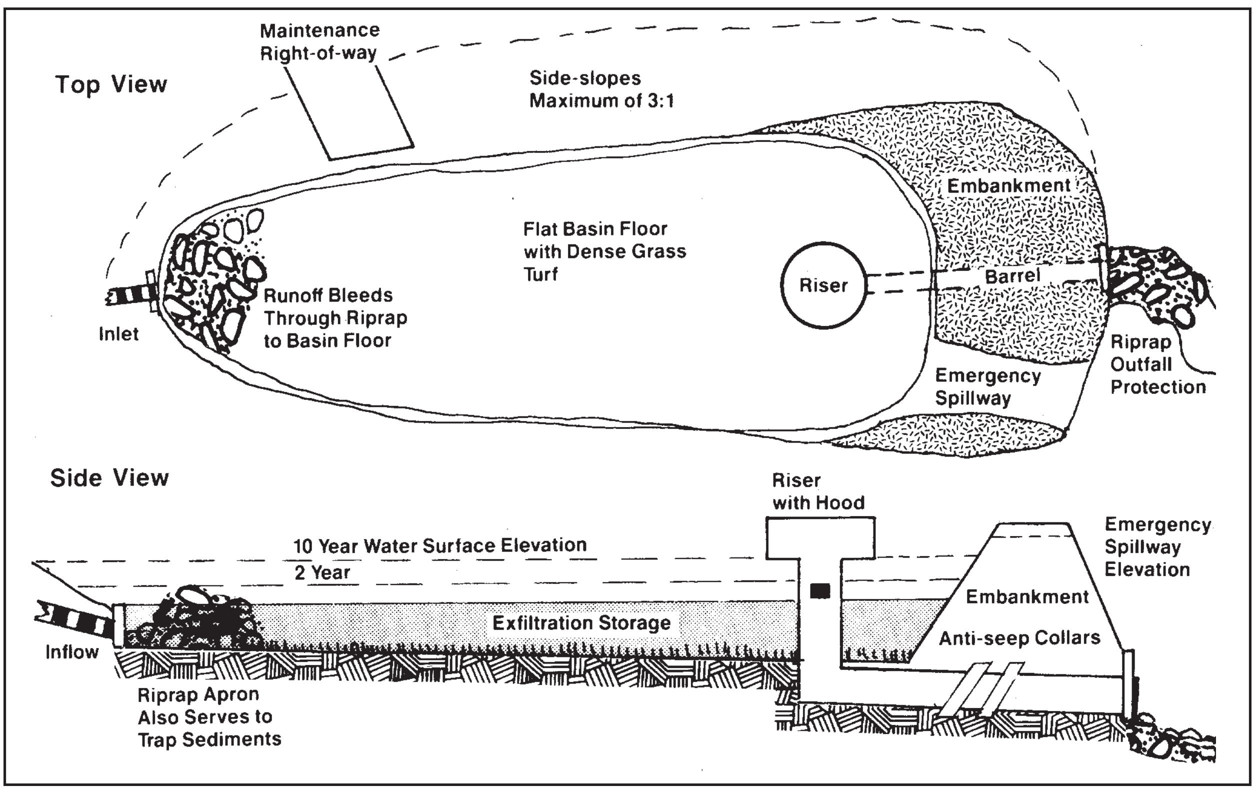
Full Infiltration Basin

This simple design is commonly used on sites with extremely permeable soils. The basin is sized to accommodate the entire runoff volume associated with the two year design storm, and the only outlet from the pond is an emergency spillway which passes larger storm events (Figure 1). A riprap apron is needed near the inlet to reduce incoming runoff velocities to promote more uniform infiltration. Otherwise, this rudimentary design has no other features for routing stormflow or baseflow through the structure. Consequently, the use of a full infiltration basin is generally restricted to smaller watersheds (5 to 20 acres) that do not have concentrated, erosive flows.

Combined Infiltration/detention Basin

This design is one of the more common infiltration basin designs in use today (Figure 2). Runoff entering the top of the basin is first trapped in a modified riprap settling basin. Coarse sediment drops out, and the remaining runoff filters through the riprap apron and is spread out over the level basin floor. The depth of runoff in the basin is controlled by a vertical riser. The 2 year control orifice is place several feet above the bottom of the pond, creating a zone of dead storage. The runoff within the dead storage zone will be completely exfiltrated. If any base flow exists, a low flow channel should be installed to pass it rapidly through the basin.

FIGURE 2: Combined Infiltration/Detention Basin Design



Runoff volume in excess of the dead storage volume drains through the low flow orifice, while the very large runoff volumes associated with the design storm spills over the drop inlet at the top of the riser. Extremely large storms (such as the 10 or 100 year storm) are routed through the basin and discharged via the emergency spillway. If the basin is located over soils with marginal infiltration capacity, it may be prudent to extend some capped underground perforated pipes from the riser to drain the basin floor in the event that exfiltration rates are overestimated. The pipes can then be uncapped later if it is found that the basin suffers from chronic standing water problems or local groundwater mounding.

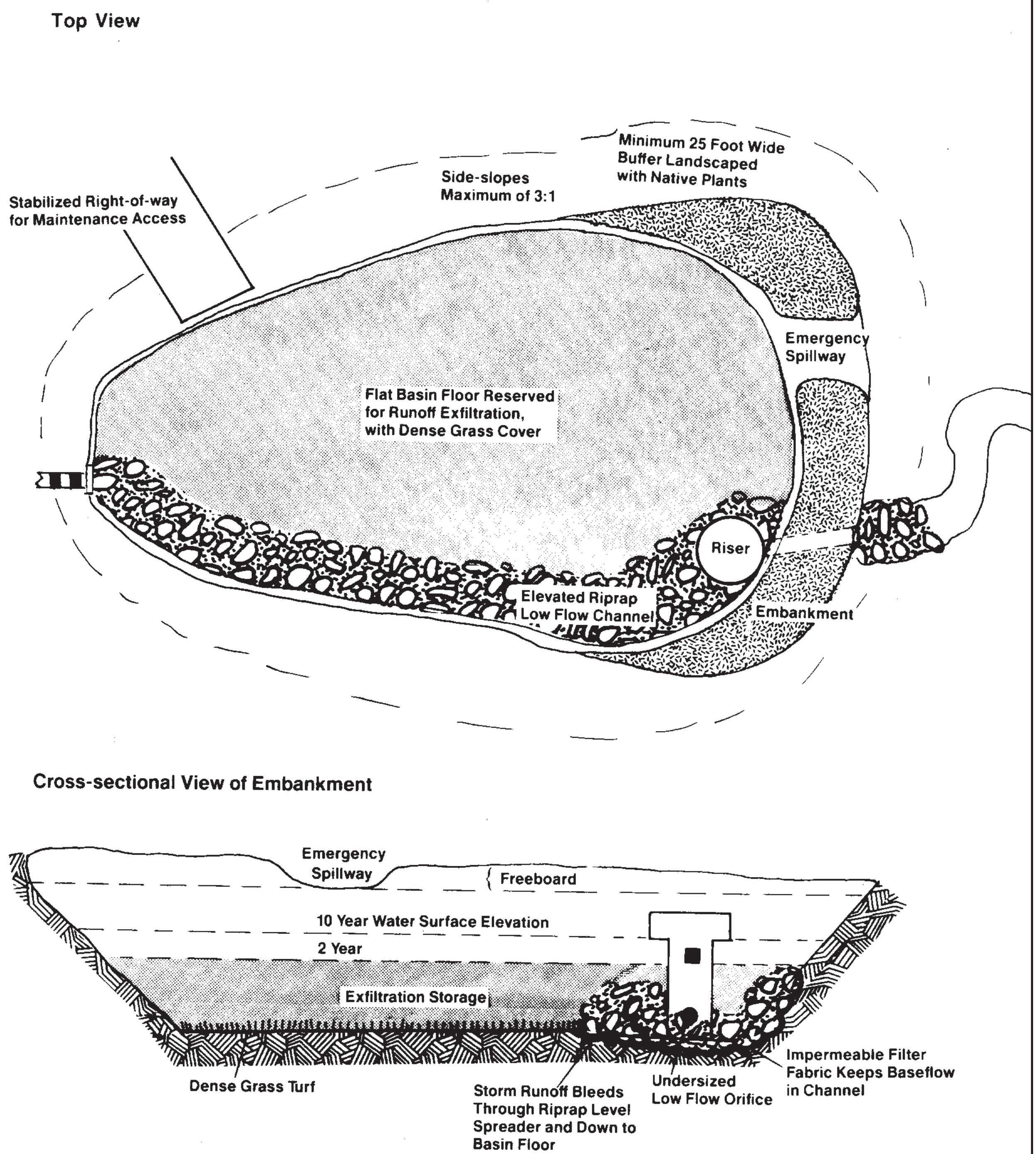
This basic design can be applied to serve most residential and commercial developments. However, it must be modified if the basin is expected to receive a sustained input of base flow or large sediment loads.

Side-by-side Basin

The design of larger infiltration basins must address the tricky problem of routing small baseflow and large storm flows through the basin, while still providing good exfiltration capability for small and moderate sized storm events. One solution is a side-by-side design (Figure 3), wherein a riprap pilot channel is constructed along one margin of the basin and extends all the way to the riser. The pilot channel is elevated several feet above the basin floor. Baseflow is confined to the pilot channel (by a layer of impermeable geo-textile) and travels directly to an undersized low flow orifice at the base of the riser and then out of the basin.

Stormflow pulses are also directed through the pilot channel. However, once incoming storm flows reach a given depth they are no longer confined by the impermeable geo-textile, and may leak through the riprap and down across the basin floor. Storm runoff that does travel all the way to the riser is then diverted down a riprap bench and back into the basin floor. The invert of the low flow orifice is set to form a dead storage zone down to the basin floor that stores the equivalent of the first flush runoff volume.

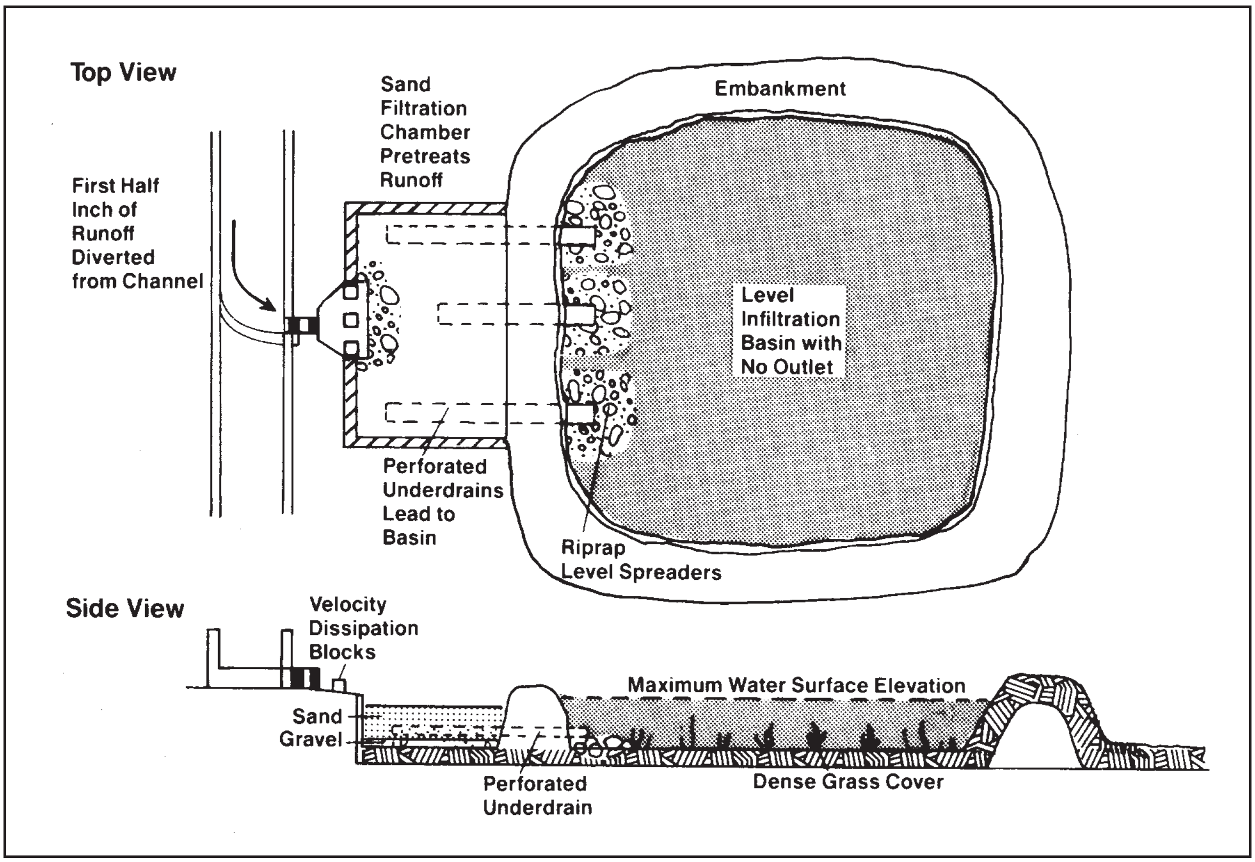
FIGURE 3: Side-by-Side Infiltration Basin Design



Off-line Infiltration Basins

Off-line designs are used to divert and exfiltrate the first flush runoff volume from a storm sewer or surface channel. They are particularly useful in development situations where exfiltration cannot be achieved by a downstream stormwater detention facility due to soil limitations. An off-line design modified from Austin DPW (1986) is shown in Figure 4. This design utilizes a combination of an off-line sand filter and infiltration basin to treat the first flush runoff volume. A weir is placed across a natural or man-made channel that diverts runoff into an off-line sand filter. After percolating through the sand filter, runoff is collected by underdrains which lead to a level, vegetated infiltration basin. This is a particularly appropriate design for sites that drain land uses which produce high sediment or hydrocarbon loads.

FIGURE 4: Off-line Infiltration Basin Design



DESIGN SUMMARY: INFILTRATION BASINS

- **SITE EVALUATION:**
  Soils must be tested prior to design to ensure that the site is capable of infiltration. Since soil characteristics vary spatially, a minimum of three soil borings and/or trenchings should be made within the basin. Each core should extend at least five feet below the anticipated floor of the basin. Soils within this zone (0 to 5 feet below basin floor) should have a minimum field infiltration rate of 0.5 inches/hr (fc), and be above the seasonally high water table and bedrock level. Basins should never be constructed over fill soils.

- **WATERSHED SIZE:**
  Full exfiltration basins can be applied on small watersheds (5 to 25 acres) that do not have a permanent source of base flow. Infiltration/detention basins can be used on larger watersheds (up to 50 acres) if there is a design feature for routing base flow through the structure without infiltrating (side-by-side design).

- **DEGREE OF EXFILTRATION:**
  To achieve significant pollutant removal and downstream channel protection, the basin should be capable of completely exfiltrating the first ½ inch of runoff per contributing impervious acre. When possible, even greater quantities of exfiltration are preferable.

- **SHAPE OF BASIN:**
  The floor of the basin should be graded as flat as possible to permit uniform ponding and exfiltration. Low spots and depressions should be leveled out. Side-slopes leading to the floor should have a maximum slope of 3:1 (h:v) to allow for easier mowing and better bank stabilization.

- **CONSTRUCTION:**
  The basin should be excavated with light equipment equipped with tracks or over-sized tires to minimize compaction of the underlying soils. After the basin is excavated to the final design elevation, the floor should be deeply tilled with a rotary tiller or disc harrow to restore infiltration rates, followed by a pass with a leveling drag. Vegetation should be established immediately. The riser, embankment, and emergency spillway should be sized and constructed to the normal specifications for conventional ponds.

- **VEGETATION:**
  The floor of the basin should be stabilized by a dense turf of water tolerant reed canary grass or tall fescue, immediately after basin construction. The grass turf promotes better infiltration, pollutant filtering, and prevents erosion of the basin floor.

- **BASIN INLETS:**
  All basins should have sediment forebays or riprap aprons that dissipate the velocity of incoming runoff, spread out the flow and trap sediments before they reach the basin floor.

- **INLET/OUTLET INVERT ELEVATIONS:**
  The storm drain inlet pipe (or channel) leading to the basin should discharge at the same invert elevation as the basin floor. Similarly, the low flow orifice in infiltration/ detention basins should be set at the same elevation as the basin floor to prevent base flow from ponding and thus impeding the function of the basin.

- **MAXIMUM DRAINING TIME:**
  As a general rule, the depth of storage should be adjusted so that the basin completely drains within 72 hours. On sites with marginal soils, or basins with a large floor, it is prudent to design the basin to drain within 48 hours. This can be accomplished by increasing the surface area of the basin floor, or by reducing the depth of storage, or both.

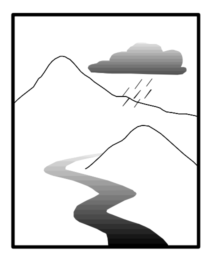
- **BASIN BUFFER:**
  A minimum buffer of 25 feet from the edge of the basin floor to the nearest adjacent lot should be reserved. A landscaping plan should be prepared for the basin buffer that emphasizes the use of low maintenance, water tolerant, native plant species that provide food and cover for wildlife, and when necessary, can act as a screen.

- **INSPECTIONS:**
  The change in standing water depth above the basin floor over time should be checked after each major storm in the first few months after basin construction to monitor exfiltration rates. Similar tests should be conducted annually to gage the degree of surface clogging that may occur over the years, and to help in scheduling restorative deep tilling operations.

- **EROSION CONTROL:**
  Infiltration basins can be used as temporary sediment control basins during the construction phase, as long as at least two feet or original soil is preserved (that will be excavated later for the basin). As with all infiltration facilities, upland construction areas should be completely stabilized prior to permanent basin construction.

- **ACCESS:**
  Adequate access to the basin floor should be provided for public or private right-of-way that can withstand light equipment. Such access should be at least 12 feet wide, and should not cross the emergency spillway.

- **MAINTENANCE**:
  Maintenance responsibilities should be clearly vested, and funds reserved for both routine and non-routine maintenance tasks. Wet weather inspections, with as-built plans in hand, should be conducted annually. The basin floor is best maintained as wet meadow, and should be mowed twice a year to prevent woody growth. If standing water becomes a problem over time due to gradual surface clogging, infiltration rates can be restored by deep tilling operations. If tilling does not solve the problem, it may be necessary to convert the basin into a wet pond or shallow marsh, or install underdrains to collect the water.



SECTION V

POROUS PAVEMENT and ALTERNATIVE SURFACES

POROUS PAVEMENT

Porous pavement has a high capability to remove both soluble and fine particulate pollutants in urban runoff, and also provides groundwater recharge, low flow augmentation, and a streambank erosion control. Its use is generally restricted to low volume parking areas, although it can accept runoff from rooftop storage or adjacent conventionally paved areas. As a BMP, porous pavement is only feasible on sites with gentle slopes, permeable soils, and relatively deep water table and bedrock levels. When these conditions are met, porous pavement is a reasonably cost effective BMP, particularly if off-site runoff contributions are not great.

When properly designed and carefully installed, porous pavement has load bearing strength, longevity, and maintenance requirements similar to conventional pavement. Some other advantages of porous pavement are reduced land consumption, reduction or elimination of the need for curb and gutters and downstream conveyance systems, the preservation of the natural water balance at the site, and a safer driving surface which offers better skid resistance and reduced hydroplaning.

The major drawback associated with porous pavement is that if it becomes clogged it is difficult and costly to rehabilitate. The risk of premature clogging of a pavement is fairly high, and can be prevented only if sediment is kept off of the pavement before, during and after construction. Other disadvantages include the need for extensive feasibility tests, inspections, very high levels of construction workmanship (which cannot always be assured), and a possible risk of groundwater contamination (probably slight).

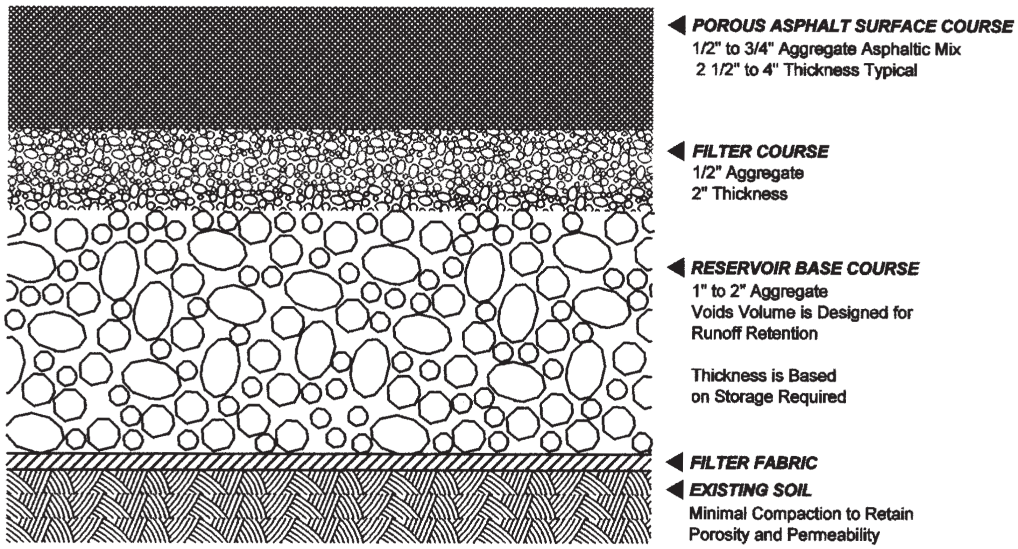
METHODS USED FOR POROUS PAVEMENT

A typical cross section of porous pavement is shown in Figure 1a. Runoff rapidly infiltrates through the pores of the 2½ to 4 inch porous asphalt layer into the void spaces of an underground stone reservoir. The reservoir is composed of two layers: a 2-inch filter course of ½-inch diameter gravel placed over a deeper reservoir course of 1 to 2 inch diameter stone. Runoff then exfiltrates out of the stone reservoir and into the underlying subsoil or is collected by perforated underdrain pipes and routed to an outflow facility. Thus, the storage capacity of porous pavement is primarily a function of the depth of the underground reservoir (plus any runoff lost via exfiltration through the subsoils). A typical layout is illustrated in Figure 1b.

Under normal conditions, the porous ashphalt layer merely acts as a rapid conduit for runoff to reach the stone reservoir (typical infiltration rates for open-graded porous asphalt are in excess of 150 inches/hour). A less preferable alternative for directing runoff into the stone reservoir is to install drop inlets or drill holes through a layer of conventional asphalt.

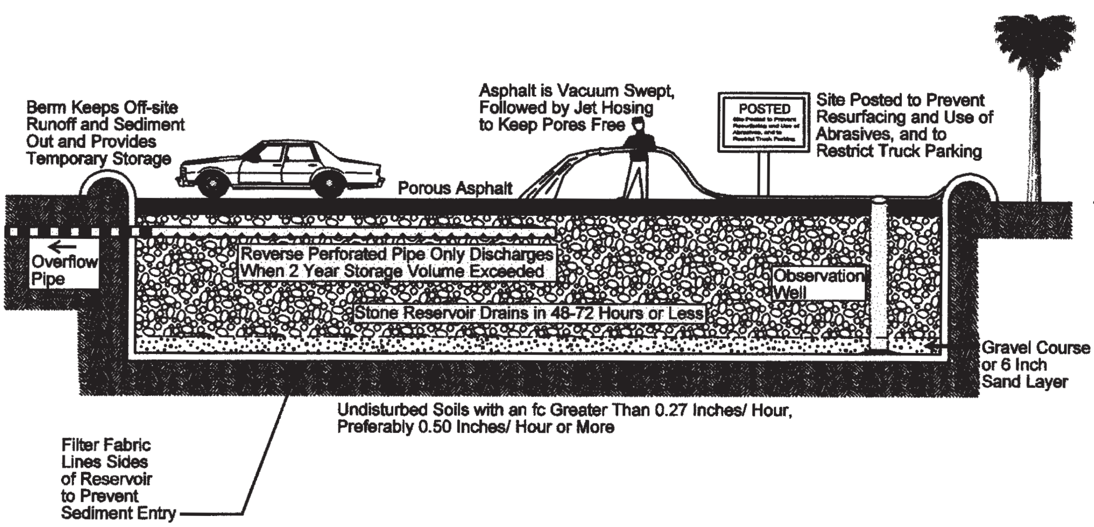
Porous pavement designs fall into three basic categories based on the runoff storage provided by the stone reservoir and the degree of reliance on exfiltration. These are described below and are illustrated in Figure 2.

Figure 1a: **Porous Asphalt Paving Typical Section**



Source: City of Rockville, Maryland

Figure 1b: **Porous Asphalt Paving Design Schematic**



Full Exfiltration System

With this design, the only way runoff can exit the stone reservoir is to exfiltrate through the underlying subsoil (i.e., there is no positive pipe outlet draining the stone reservoir). Consequently, the stone reservoir must be large enough to accommodate the entire increase in runoff volume for the design storm, less any runoff volume which is exfiltrated during a storm. The complete exfiltration system provides total peak discharge, volume, and water quality control for all rainfall events less than or equal to the design storm. An emergency overflow channel (such as a raised curb) is located above ground to handle the excess runoff from storms greater than the design storm.

Partial Exfiltration System (Stone Filtration System)

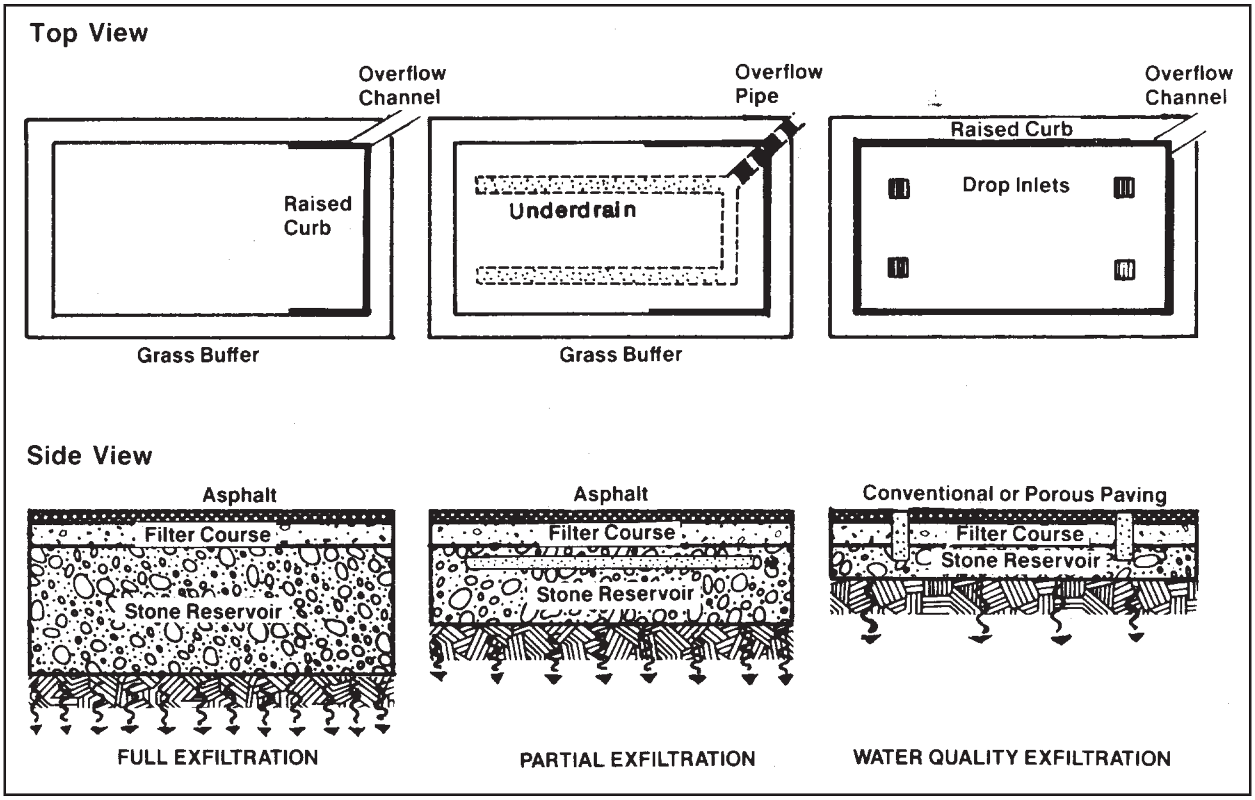
It may not always be feasible or prudent to totally rely on exfiltration to dispose of runoff. For example, there may be concerns about the long term permeability of the underlying soils, downstream seepage, or clogging at the interface between the filter fabric and subsoil. In these situations, an underground drainage system can be installed, comprised of regularly spaced perforated pipes located in shallow depressions that collect the runoff and direct it to a central outlet. The size and spacing of the underdrain network is set to pass the 2 year storm. However, most of the runoff volume from smaller storms will still be exfiltrated before it is collected, thereby providing significant water quality control.

An alternative method of controlling the design storm in partial exfiltration systems is to place perforated pipes (on the underside only) near the top of the stone reservoir (NVPDC, 1987). Runoff then must entirely fill up the stone reservoir before it is discharged from the facility. This design should promote a greater degree of exfiltration, particularly for smaller storms.

Water Quality Exfiltration System

With the water quality design, the storage volume of the stone reservoir is set to only handle the first flush of runoff volume during a storm. The first flush has been variously defined as 1) ½ inch of runoff per contributing impervious acre, 2) ½ inch runoff per contributing total acres, and 3) the volume of runoff produced by a 1-inch storm. Runoff volumes in excess of the first flush are not treated by the system, and instead, are conveyed to a conventional stormwater management facility further downstream. Water quality exfiltration system will not satisfy stormwater storage requirements, but may result in smaller, less costly facilities downstream. In most sites, the first flush runoff volume can fit within the normal 6-inch layer of stone aggregate required for conventional paving. Slot or drop inlets through conventional asphalt can be used in addition to porous asphalt to route the first flush into the stone reservoir.

FIGURE 2: Comparison of Selected Exfiltration Systems for Porous Pavement



A design variation that enables a porous pavement site to accept runoff contributed from off-site areas is shown in Figure 3. As shown, a series of underground perforated inflow pipes are used to convey runoff into the porous pavement and evenly distribute it throughout the stone reservoir. In addition, a pretreatment facility is needed to remove sediment, oil and grit before it reaches the reservoir. Some useful pretreatment techniques for porous pavement are shown in Figure 4.

FIGURE 3: Design Technique for Accepting Off-Site Runoff

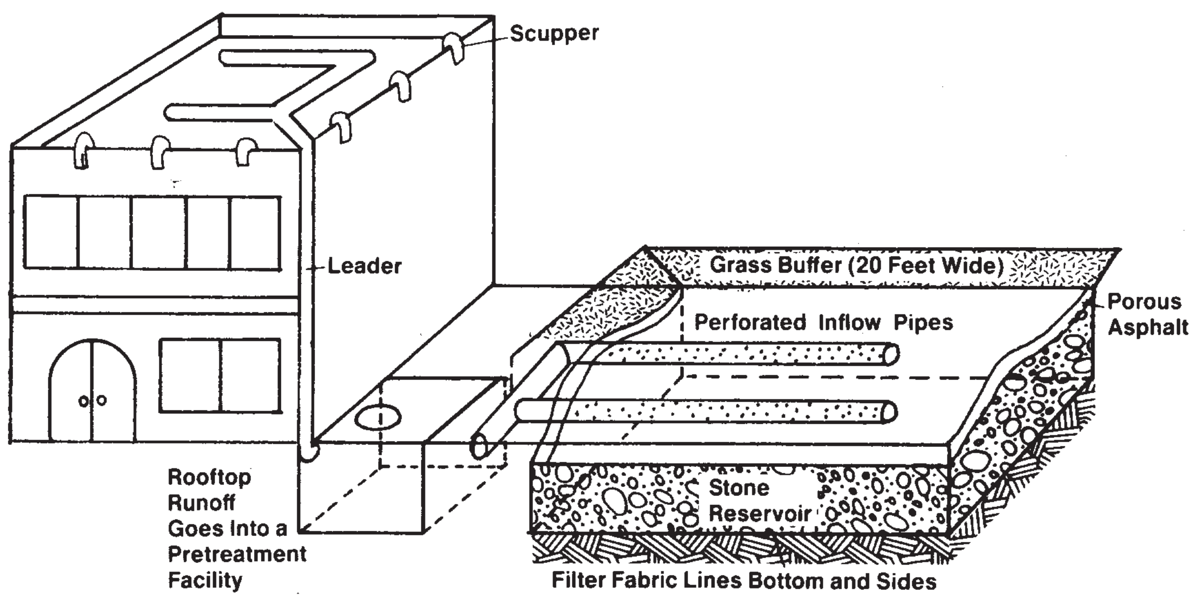
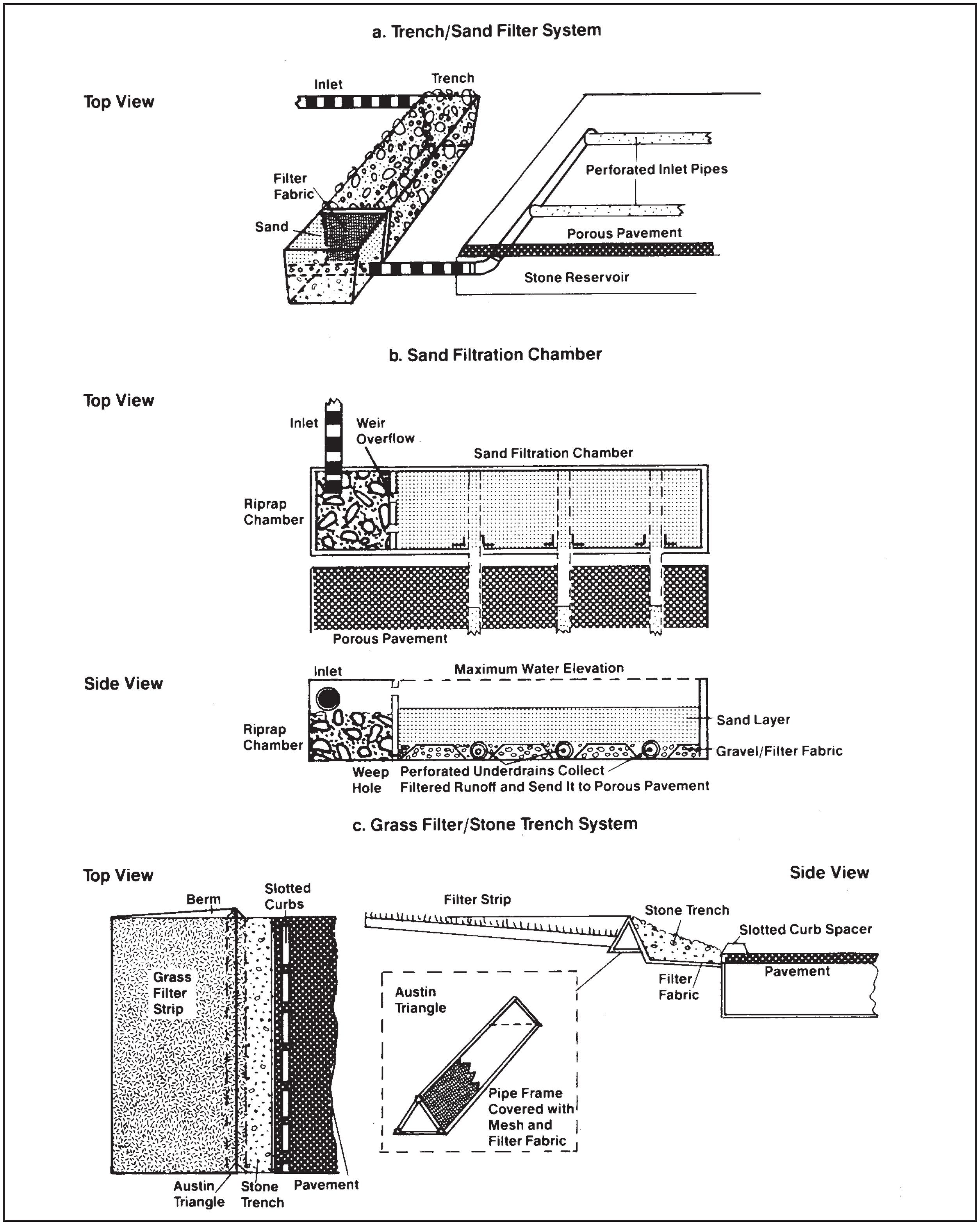


FIGURE 4: Pretreatment Methods For Porous Pavement Sites



DESIGN SUMMARY: POROUS PAVEMENT

- **SITE ELEVATION:**
  Prior to design, the site should be carefully evaluated to determine whether it is feasible for infiltration. This involves taking at least three soil borings or trenches, to a depth of 4 feet below the anticipated bottom of the stone reservoir. Evidence of the seasonally high water table, bedrock level, fill soils, or localized clay lenses should not be present in the cores. Underlying soils should have a minimum infiltration rate of 0.27 in./hr. (for partial exfiltration systems) or 0.52 in./hr. (for full exfiltration systems).

- **TRAFFIC INTENSITY:**
  Porous pavement is generally only feasible for low volume automobile parking areas (0.25 to 10.0 acres in size), and lightly used access roads. Areas within a large parking lot that are expected to receive moderate or heavy traffic intensity, or that will accommodate heavy trucks, can be conventionally paved and then sloped to drain over to an adjacent porous pavement area.

- **DEGREE OF EXFILTRATION:**
  Most porous pavement applications will be of the full or partial exfiltration variety, and should be designed to exfiltrate a minimum of runoff volume equivalent to the first ½ inch of runoff from contributing impervious areas.

- **SLOPE:**
  The slope of porous pavement should not exceed 5% and is best when as flat as possible. If low spots do develop in the parking lot, it may be advisable to install drop inlets to divert runoff into the stone reservoir more quickly.

- **CONSTRUCTION:**
  Probably more than any other BMP, porous pavement requires a high level of construction expertise and workmanship. The construction specifications presented in Reference 1 may be used as a guideline.

- **MAXIMUM DRAINING TIME:**
  The depth of the stone reservoir should be adjusted so it drains completely within 72 hours. This allows the underlying soils to dry out between storms (improving pollutant removal), and also preserves capacity for the next storm. If the site has marginal soils for infiltration (loams, silt loams), or covers a wide area, it may be prudent to design the reservoir to drain within 48 hours.

- **MINIMUM DRAINING TIME:**
  Care should be taken in spacing the underdrain network in partial exfiltration systems. If perforated underdrains are spaced too close together, runoff may be collected too efficiently to provide the exfiltration needed for high pollutant removal. As a general design rule, a minimum residence time of 12 hours (as determined by the modified TR-20 procedure for infiltration facilities) should be a target for the design event.

- **OBSERVATION WELLS**:
  An observation well, consisting of a well-anchored, vertical perforated PVC pipe with a lockable above ground cap, should be installed on the downslope end of the porous pavement area to monitor runoff clearance rates. The well should be checked several times in the first few months after construction. Water depth in the well should be measured at 0, 24 and 48 hour intervals after a storm. Clearance rates are calculated by dividing the drop in water level (inches) by the time elapsed (hours) from the end of the storm. A series of clearance rate measurements taken over the years provides a useful tool for tracking any clogging problems within the stone reservoir.

- **POSTING:**
  The porous pavement site should be posted with signs indicating the nature of the surface, and warning against resurfacing the site with conventional pavement, using abrasives (such as sand or ash) for snow removal, or parking of heavy construction equipment.

- **EROSION CONTROL:**
  Sediment must be kept completely away from a porous pavement site before, during and after construction. Diversion berms should be used to divert stormwater and sediment around the planned porous pavement site. Porous pavement construction should never begin until all contributing upland areas have been completely stabilized. Soil excavated during construction should be placed well away from the perimeter of the site to prevent it from washing back into the stone reservoir.

- **PRETREATMENT OF RUNOFF:**
  If the porous pavement site receives runoff from off-site areas, a pretreatment facility should be constructed to remove oil, grit and sediments before they can enter the stone reservoir and possibly clog it. Sand filters, water quality inlets, short trenches or barrel inlets (rooftop runoff only) can be used for this purpose.

- **VACUUM SWEEPING/JET HOSING:**
  The pavement surface should be vacuum swept at least four times per year to remove any grit or sediment trapped in the pores of the open-graded asphalt. This treatment should be immediately followed by high pressure jet hosing to wash off any remaining fine particles. Evidence of a regular service contract for performing this important maintenance activity should be required before any bonds are released on a project.

- **INSPECTIONS:**
  Each site should be inspected annually during wet weather to check the clearance rate of the stone reservoir, and to inspect the condition of buffer strips, pretreatment facilities, and any evidence of surface clogging.

- **CLOGGING/REPAIRS:**
  Potholes, cracks and other pavement defects can be patched with conventional paving mixes, as long as the cumulative total area repaired is less than 10% of the total area. If the regular vacuum sweeping/hosing routine does not relieve surface clogging, ½-inch diameter holes can be drilled through the asphalt course into the stone reservoir to facilitate drainage. If the stone reservoir or subsoil becomes clogged, the structure may have to be replaced, unless a backup system of underdrains is provided.

ALTERNATIVE SURFACES

As long as we depend on cars, we will need roads, parking lots, and driveways. Asphalt and concrete are the most common types of driving surfaces, but are very impervious (hard and water resistant). Alternative surfaces are more pervious than asphalt or concrete. Some let a little rain seep (infiltrate) into the ground, while others let 100 percent of the rain infiltrate. The more rain we infiltrate, the less runoff we create. The less runoff, the fewer pipes and storage systems we need to build in order to prevent flooding. Alternative surfaces include paving blocks, plastic matting, gravel, bark, and similar materials.

Paving Blocks

Interlocking high-strength blocks made of concrete, cement or recycled plastic with open areas for grass or gravel are commonly referred to as paving blocks. These blocks are typically set on a compacted base of sand or a mix of sand and gravel. No mortar is required. Sand is vibrated into the space between the units causing them to interlock and form a tough, attractive surface. They support fairly heavy traffic and concentrated loads, reduce stormwater runoff, enhance groundwater recharge, and increase infiltration.

Figure 5a shows typical blocks, with hollow centers which can be filled with sand or soil and planted with vegetation. Runoff quantity reduction occurs as infiltration takes place in the planted areas.

Plastic Matting

This type of system is usually a form of easily laid locking tiles made from recycled rubber tires and PVC, permitting thick grass to grow up through holes in the matting. It is often used to create safer, more natural playground, recreational, and sport surfaces, and can be an excellent application for pedestrian walkways. It typically infiltrates 100 percent and can be easily disassembled and relocated. Some plastic matting meets the Americans with Disabilities Act guidelines for wheelchairs.

Gravel, Bark, and Similar Materials

As long as these are placed over soil that is not already compacted, they will allow water to infiltrate back into the ground. Gravel, bark, and similar materials are practical for trails, bike paths, and walkways.

Application

Alternative Surfaces are appropriate for low traffic areas where there are few sources of pollutants, including:

* Fringe or overflow parking areas
* Emergency parking and stopping lanes
* Private roads, easement service roads, and fire lanes
* Driveways in residential or light commercial zones
* Bike paths, walkways, and patios

In parking lots for retail stores, sports arenas, civic theaters, and the like, where more than half of the parking area is used less than 20 percent of the time, the use of parking blocks in the less-used portions of such lots give them a much more attractive appearance and will considerably reduce runoff quantity, flow rates, and pollution from these areas.

Design Guidelines

There are some common problems that can arise if alternative surfaces are not installed and maintained properly. To avoid problems:

* Select the appropriate alternative surface to meet your objective (infiltration; reduce runoff, flooding, and erosion; aesthetics; soil stabilization; etc.).

* Locate paving blocks where they will not become clogged with dirt. If it is a new site, make sure the soil is stabilized before installing the blocks.

* Use alternative surfaces where there are few pollutants and where the water table is well below the ground surface. This will keep our groundwater and drinking water free from pollutants.

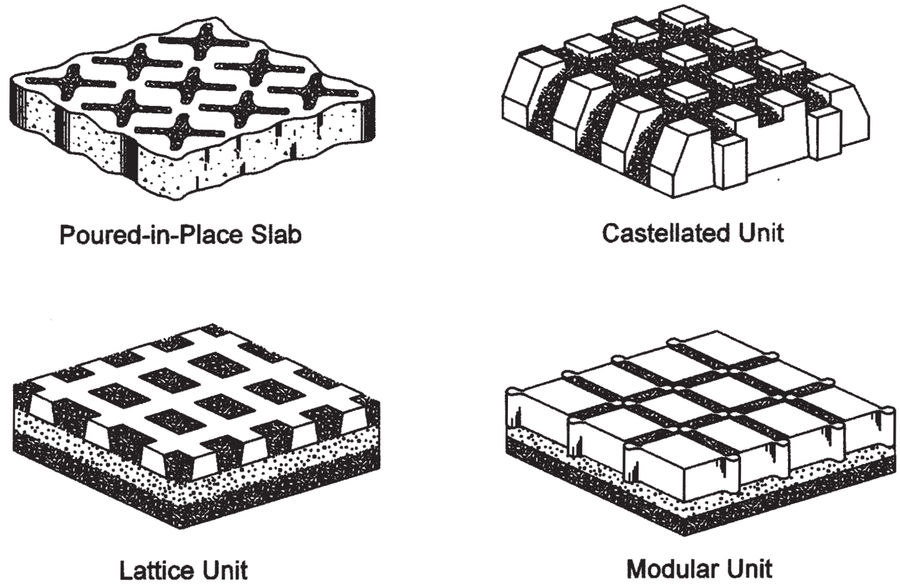
* Use alternative surfaces on gentle slopes and where the soil is porous or loose enough to let water soak in.

* Avoid using alternative surfaces for high traffic walkways and handicapped parking areas. Select paving blocks or plastic matting with small holes and locate them in “low traffic areas”.

* In designing a paving block area, the block manufacturer should be consulted to determine the more suitable subbase to use. Also, it is suggested that only the actual parking spaces should be paved with the blocks, since they do not hold up well under traffic. A typical layout is illustrated in Figure 5b. The normal traffic lanes through the lot could be paved with porous pavement.

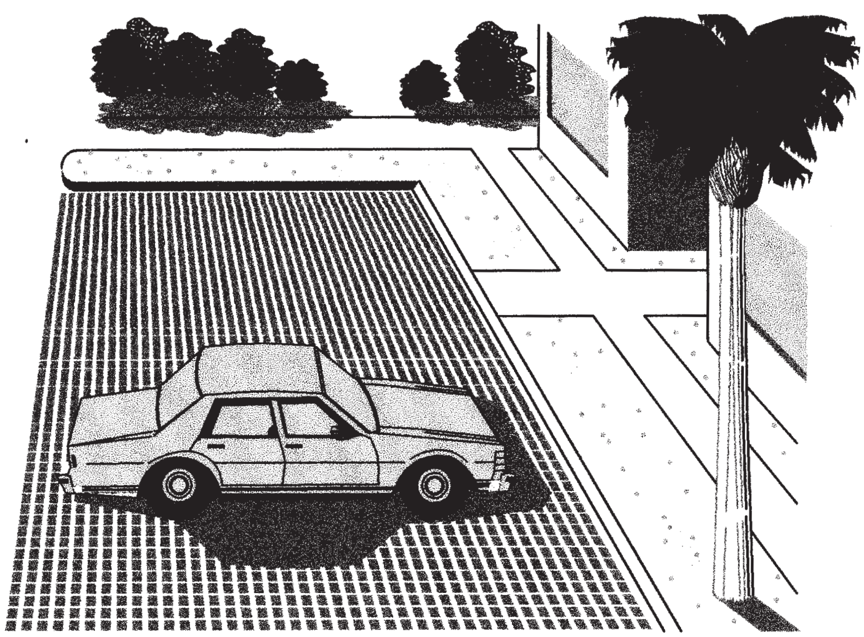
* Finally it should be noted that vegetated paving blocks are best suited for use where the natural frequency of rain is sufficient to keep the planted grass alive. In arid areas, this control should not be used unless provisions for watering is made. When the grassed areas are not well-maintained and the grass has been allowed to die, soil erosion inevitably occurs and use of the parking lot during rainstorms results in muddy shoes. Also, care must be taken when walking on this type of pavement in high heels.

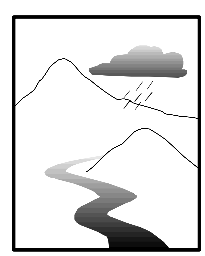
Figure 5a: **Types of Grid and Modular Pavement**



Source: Virginia Soil and Water Conservation Commission

Figure 5b: **Typical Parking Lot Layout Using Grid or Modular Pavements**





SECTION V

SAND FILTERS

Sand filters are a relatively new technique for treating stormwater, whereby the first flush of runoff is diverted onto a self-contained bed of sand. The runoff is then strained through the sand, collected in underground pipes and returned back to the stream or channel. Sand filters are useful in watersheds where concerns over groundwater quality prevent use of infiltration.

Sand filters have many advantages. They have a moderate to high pollutant removal capability, possess very few environmental limitations, require small amounts of land, and can be applied to most development sites, large or small. They can be used on areas with thin soils, high evaporation rates, low soils infiltration rates, and limited space. Most sand filters have been used on small parking lots.

Nearly a dozen variants of the basic sand filter design are currently in use, and engineers and practitioners continue to create more. Some of the more common designs are illustrated in Figure 1. Each sand filter design utilizes a slightly different profile within the filter bed.

The required surface area of the filter is usually a direct function of the impervious acreage treated, and varies regionally due to rainfall patterns and local criteria for the volume needed for water quality treatment. The drawback is that sand filters do not provide stormwater quantity control.

Feasibility

The primary physical requirement is a minimum of 2 or 3 feet of head differential existing between the inlet and outlet of the filter bed. This is needed to provide gravity flow through the bed. Otherwise, use of sand filters is only limited by their cost and local maintenance capability.

Pollutant Removal

Initial monitoring results suggest that sand filters are very effective in removing particulate pollutants such as total suspended solids, lead, zinc, organic carbon, and organic nitrogen. Removal rates in excess of 75% have been frequently observed for each of these parameters. Removal rates for coliform bacteria, ammonia, ortho phosphorus, and copper were moderate and quite variable. Results ranged from 20% to 75% in the four sand filters tested in Austin, Texas. Negative removal rates were frequently reported for total dissolved solids (TDS) and nitrate-nitrogen.

Design

Designers are constantly refining the basic sand filter design to increase the level and consistency of nutrient and bacteria removal. A popular approach has been to add an additional organic layer to the filter bed to increase pollutant removal capability. A series of organic media have been used including a top layer of grass/soil, grass/peat or compost, a middle layer of peat, activated carbon, and even zeolites.

The limited data on "sandwich systems" so far indicates that the sandwich layer could actually be a source for some pollutants, while effectively trapping others. Perhaps the most reliable option for improving sand filter performance is to combine a filter with another BMP such as a grass swale or filter strip. Since sand filters are basically similar to infiltration trenches, the reader is encouraged to look at the "Design Summary" of the Infiltration Trenches section in this manual for further guidance.

Maintenance

Regular maintenance is an essential component of the operation of a sand filter. At least once a year each filter should be inspected after a storm to assess the filtration capacity of the filter bed. Most filters exhibit diminished capacity after a few years due to surface clogging by organic matter, fine silts, hydrocarbons, and algal matter.

Maintenance operations to restore the filtration capacity are relatively simple and consistent of manual removal of the top few inches of discolored sand followed by replacement with fresh sand. The contaminated sand is then dewatered and landfilled. Testing by the Austin Department of Public Works indicates that the sediments are not toxic and can be landfilled. Based on one sample from a Delaware site, sand filter deposits appear to have the same degree of sediment contamination as pond muck and thus may not pose a risk for land disposal. This conclusion, however, should be considered provisional until further testing of more filter sediments are obtained from sites that are heavily influenced by automotive or industrial uses.

The key point is that the operation of the sand filter requires replacement of the surface sand layer on a relatively frequent basis. A number of techniques are being developed to reduce the frequency of sand replacement or to make the operation more convenient.

* Careful Selection of Sod. Some sand filters that are constructed with a grass cover crop have lost significant filtration capability soon after construction. The clogging is often traced to sod that has an unusually high fraction of fine silts and clays. In other situations, grass roots grow into the sand layer and improve the filtration rate.

* Limiting Use of Filter Fabric to Separate Layers. Often the loss of filtration capacity occurs where filter fabric is used to separate different layers or media within the filter bed, such as in "sandwich" filters. As a general rule, the less use of filter fabric to separate layers, the better. In many situations, layers of different media can be integrated together at the boundary (e.g., 50/50 peat/sand), or by a shallow layer of pea gravel.

* Providing Easier Access. During sand replacement operations, heavy and often wet sand must be manually removed from the filter bed. It is surprising that so few designs help a maintenance worker conveniently perform this operation. It is not uncommon that sand must be lifted 6 feet or higher to get it out of the filter bed. Yet typically no ramps, manhole steps, or ringbolts are provided to make the operation easier.

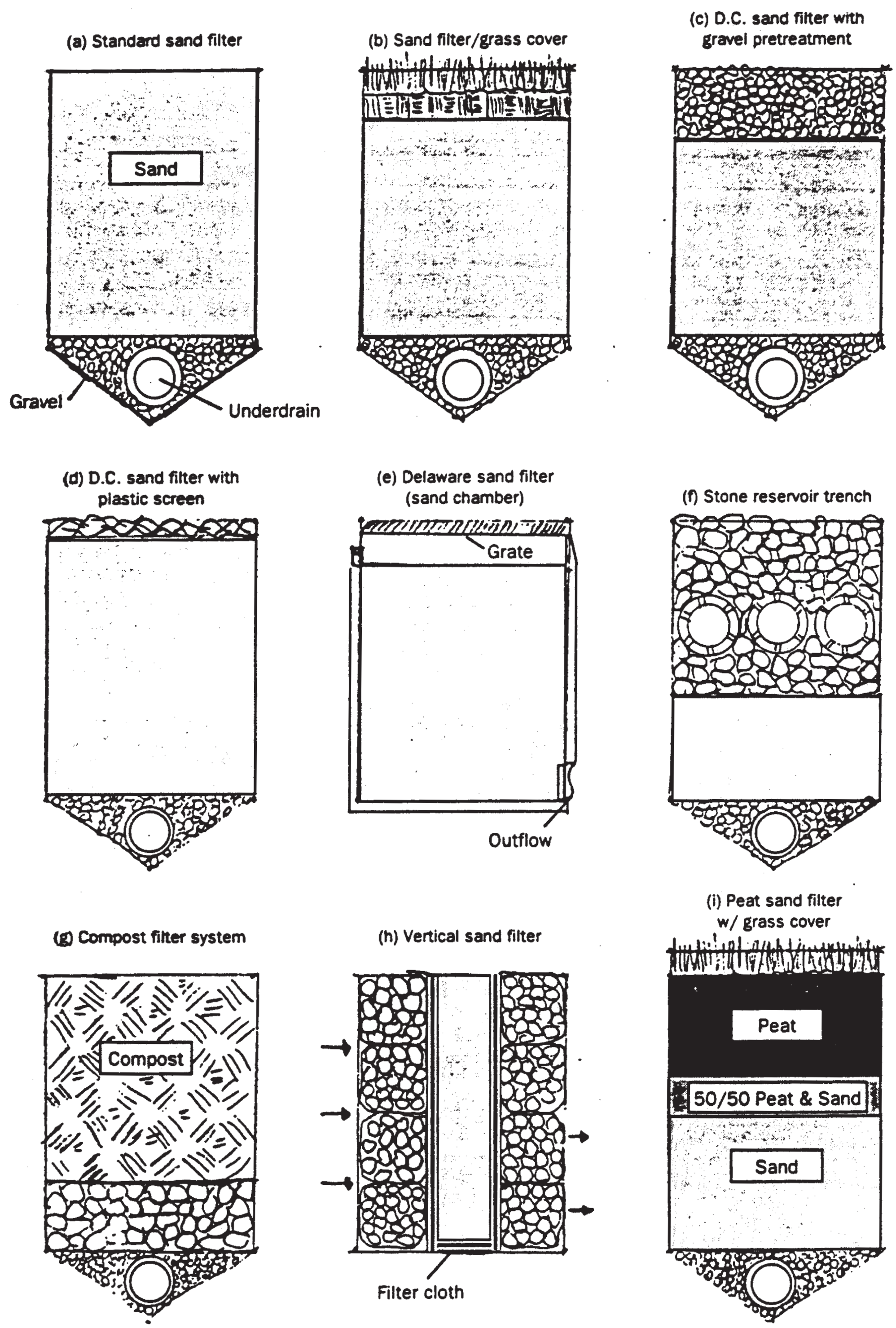
* Visibility and Simplicity. When tinkering with new sand filter designs, two key principles should be kept in mind. First, the filter should be visible, i.e., that it be easily recognized as a BMP (so that it can be routinely inspected). This often requires the designer to consider the appearance and aesthetics of the final product so that it does not come to resemble a concrete sand box. The surface of sand filters can be extremely unattractive; some sand filters have caused odor problems. The second principle is that the design should be kept as simple as possible. Experience has shown that overly complex designs create greater operation and maintenance costs.

Care should be exercised in approving sand filters for individual lots and residential developments, as most homeowners lack the incentives or resources to regularly perform needed sand replacement operations.

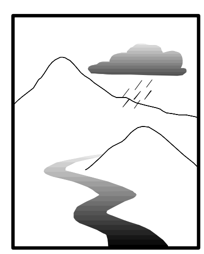
Economics

Sand filters are more costly than infiltration trenches (by a factor of two or three), but have lower regular maintenance/rehab costs. Ultimately, however, the growth in the application of sand filters will be constrained by cost and maintenance factors. Continued effort is needed to monitor the operation of sand filters. Such data could yield reductions in the costs of constructing and maintaining filters. If such cost reductions can be realized, sand filters will become an attractive option over a much wider range of development conditions.

FIGURE 1: Cross Section of Sand Filter Design Variations



Source: Watershed Protection Techniques. Vol. 1 No. 2 Summer 1994



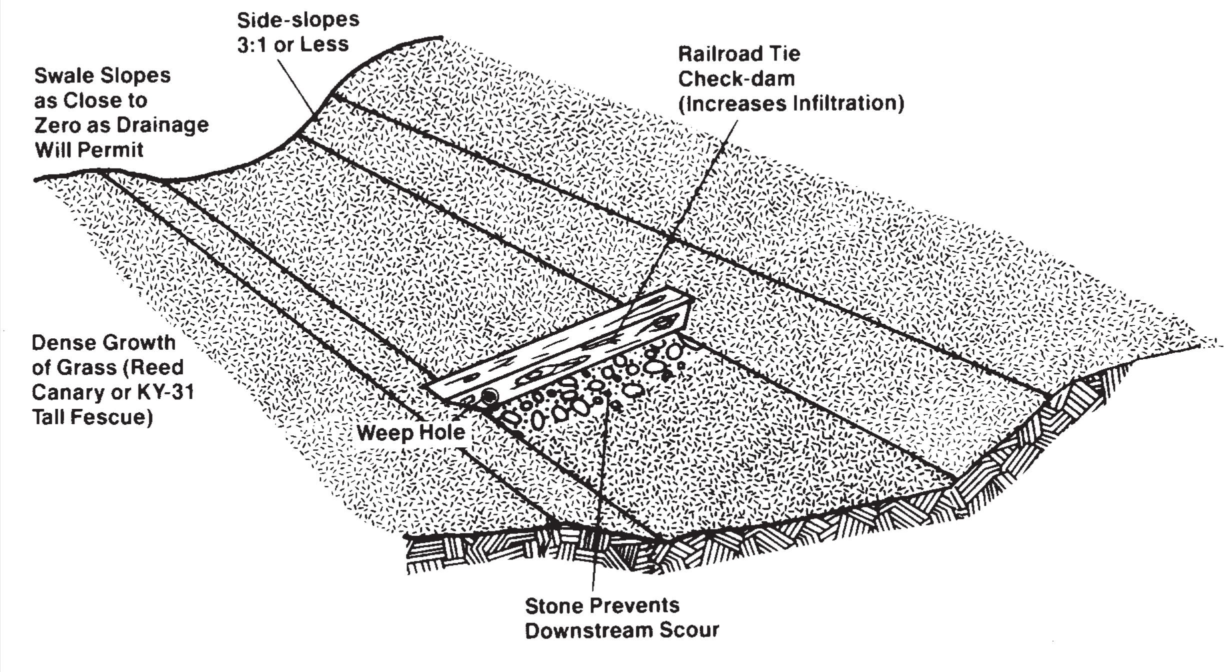
SECTION V

GRASSED SWALES

Vegetated swales are broad shallow channels which are enhanced with a dense layer of vegetation and are designed to promote infiltration, slow runoff velocities, and trap pollutants. Grassed swales are typically applied in single family residential developments and highway medians as an alternative to curb and gutter drainage systems (Figure 1).

Swales have a limited capacity to accept runoff from large design storms, and often must lead into storm drain inlets to prevent large, concentrated flows from gullying/eroding the swales. If check dams are placed across the flow path, swales can provide some stormwater management for small design storms by infiltration and flow attenuation. In most cases, however, swales must by used in combination with other BMPs downstream to meet stormwater management requirements. Grassed swales are usually less expensive than the curb and gutter alternative.

FIGURE 1: Schematic of a Grassed Swale



Stormwater Benefits

Swales act to control peak discharges in two ways. First, the grass reduces runoff velocity, depending on the length and slope of the swale. This, in turn, lengthens the watershed time of concentration (i.e., the time needed for runoff to reach the desired control point), and can, at least partially, attenuate the post-development peak discharge rate.

Second, a portion of the stormwater runoff volume passing through the swale infiltrates into the soil and does not appear at the downstream control point. However, as Wong and McCuen (1982) note, the volume of runoff that infiltrates into a swale is limited, seldom exceeding a few tenths of an inch, again depending on soils and slope.

Pollutant Removal

Pollutants are removed by the filtering action of the grass, deposition in low velocity areas, or by infiltration into the subsoil. Some modeling efforts and field studies indicate that swales can filter out particulate pollutants, under certain site conditions. However, swales are not generally capable of removing soluble pollutants, such as nutrients. In some cases, trace metals leached from swale culverts and nutrients leached from intensive lawn fertilization may actually increase the export of these pollutants.

In general, the higher the flow rate, the lower the efficiency. Thus, low velocity and shallow depth are key design criteria. A swale designed with a low bottom slope and check dams will perform much more efficiently than one without check dams. Raised driveway culverts are very effective as swale check dams. For maximum efficiency of pollutant removal during small storms, a trapezoidal swale with as large a bottom width as can be fitted into the site plan is desirable, since this will maximize the amount of runoff in contact with the vegetation and soil.

Maintenance

Maintenance is an important consideration, for reasons of both aesthetics and hydraulic efficiency. Care must be taken to ensure that flows through a swale used for drainage purposes during large storms are not impeded by an overgrowth of vegetation. To prevent this, vegetation planted in the channel should be suitable for mowing, and the channel designed so that mowing machines can be easily and efficiently operated along the swale. Permanent vegetated channels should be mowed periodically to maintain their capacity. Any areas where erosion is occurring should be repaired/revegetated as necessary.

DESIGN SUMMARY: GRASSED SWALES

* **FLOW CAPACITY:**
Design equations for flow are those used for open channel design for the small design storm, with the roughness coefficient suitably adjusted for the grass or vegetation on the channel hydraulic radius. If the soil is sufficiently permeable that infiltration through the bottom is significant, this may be taken into account in the channel design. Avellaneda (1985) and Wanilista et al. (1986) provides some guidance in this area.

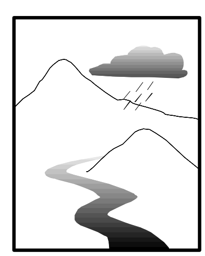
* **SLOPE:**
Swale slopes need to be graded as close to zero as drainage will permit. Side-slopes should be no greater than 3:1.

* **COVER:**
The grass type should be appropriate for the site conditions. The vegetation should have a dense root system, erosion resistant and be water tolerant. Reed canary grass should be considered. Swale grasses should never be mowed close to the ground, as this impedes the filtering and hydraulic functions of the swale.

* **SOILS:**
Underlying soils need to have an infiltration rate of 0.27 inches/hour or greater (Source: MNPCA, 1991). The swale should be tilled before the grass cover is established to restore infiltration capacity lost as a result of prior construction activities.

* **CHECK DAMS:**
Check dams can be installed in swales to promote additional infiltration. The best method is to sink a railroad tie halfway into the swale, and place stone on the downstream side of the tie to prevent a scour hole from forming. Earthen check dams are not strongly recommended as they tend to erode on the downstream side (which may lead to the eventual wash out of the dam). It is also quite difficult to establish and maintain grass on earthen check dams. If a check dam is used, the designer should make sure that the maximum ponding time of runoff backed up behind the check dam is less than 24 hours.

* **SUITABILITY:**
Swales are not likely to confer many stormwater or water quality benefits if constructed on slopes greater than 5%, or if groundwater extends to within two feet of the bottom of the swale. Long, relatively flat slopes where sheet flow occurs are ideal.



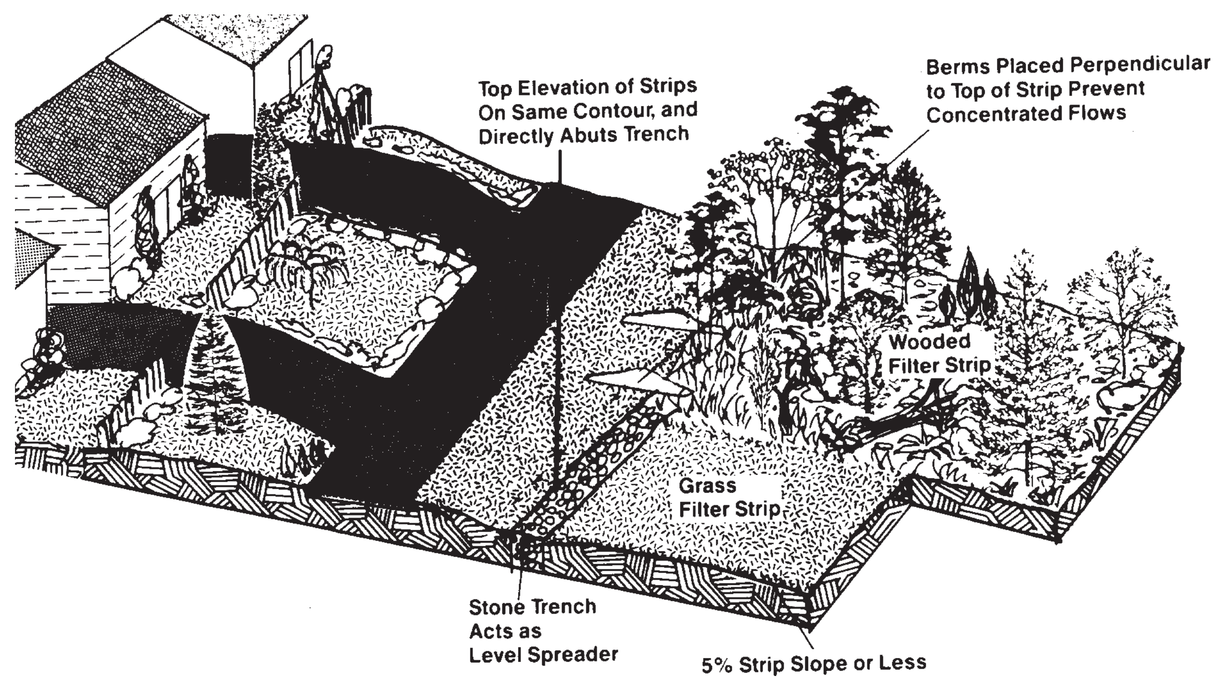
SECTION V

FILTER STRIPS

Vegetated buffer strips are dense areas of vegetation which are designed to decrease runoff velocity, promote (limited) infiltration and trap pollutants. Filter strips are similar in many respects to grassed swales (Figure 1), except that they are designed to only accept overland sheet flow. Runoff from an adjacent impervious area must be evenly distributed across the filter strips. This is not an easy task, as runoff has a strong tendency to concentrate and form a channel. Once a channel is formed, the filter strip is effectively by-passed and will not perform as designed. Such by-pass is a common problem. For example, over 60% of the agricultural filter strips installed in Virginia were reported to have been by-passed (Dilhalla et al., 1986).

To work properly, a filter strip must be 1) equipped with some sort of level spreading device, 2) densely vegetated with a mix of erosion resistant plant species that effectively bind the soil, 3) graded to a uniform, even, and relatively low slope (one technique that is effective in minimizing the grade in the direction of flow is terracing), and 4) be at least as long as the contributing runoff area. Filter strips are relatively inexpensive to establish, and cost almost nothing if preserved before the site is developed. If buffer strips are established through the preservation of existing vegetation, good site planning and site management are needed to protect against disturbances such as grade changes, excavation, damage from equipment and other activities. A creatively landscaped filter strip can become a valuable community amenity, providing wildlife habitat, screening, and stream protection.

FIGURE 1: Schematic of a Filter Strip



Stormwater Benefits

Filter strips do not provide enough storage or infiltration to effectively reduce peak discharges to predevelopment levels for design storms (Wong and McCuen, 1982). Typically, filter strips are viewed as one component in an integrated stormwater management system. Thus, the strips can lower runoff velocity (and, consequently, the watershed time of concentration), slightly reduce both runoff volume and watershed imperviousness, and contribute to groundwater recharge. At some sites, filter strips may help to reduce the size and cost of downstream control facilities. Filter strips are also of great value in preserving the riparian zone and stabilizing streambanks.

Pollutant Removal

Results from some small test plots (Barfield et al., 1977) and several modeling studies (Wong and McCuen, 1982, Pitt, 1986, Overcash et al., 1981; Tolner et al., 1982) all suggest that filter strips are effective in removing particulate pollutants such as sediment, organic material and many trace metals. The rate of removal appears to be a function of the length, slope and soil permeability of the strip, the size of the contributing runoff area, and the runoff velocity. Removal of soluble pollutants in filter strips is accomplished when the pollutants infiltrate into the soil and are subsequently taken up by rooted vegetation. The efficiency of soluble pollutant removal in strips is probably not great since only a modest portion of the incoming runoff will be infiltrated (Wong and McCuen, 1982).

Suitability

Filter strips will not function as intended on slopes greater than 15%. Those steeper slopes should still be vegetated but off-site runoff should be diverted around rather than through them. Filter strip performance is best on slopes with a grade of 5% or less. When the minimum length, 20-foot filter strips are used, slopes should be graded as close to zero as drainage permits. To prevent concentrated flows from forming, it is advisable to have each filter strip serve a contributing area of five acres or less.

Buffer strips are particularly effective on flood plains, next to wetlands, along streambanks and along the perimeter of other stormwater management facilities such as basins and retention ponds. Grass filter strips are also extensively used to protect surface infiltration trenches from clogging by sediment.

Maintenance

The maintenance required for a filter strip depends on whether or not natural vegetative succession is allowed to proceed. Under most conditions, the gradual transformation from grass to meadow to second growth forest will enhance rather than detract from the performance of longer filter strips. This process, which may be largely completed in a few decades, can be enhanced by intentional landscape plantings. Maintenance tasks and costs are both sharply reduced for these "natural" filter strips. However, corrective maintenance is still needed around the edge of the strip to prevent concentrated flows from forming.

Shorter filter strips must be managed as a lawn or short grass meadow. These strips should be mowed 2 to 3 times a year to suppress weeds and interrupt natural succession. Periodic spot repair, watering and fertilization may be required to maintain a dense, vigorous growth of vegetation. Weed and pest control may also be required. Accumulated sediments deposited near the top of the strip will need to be manually removed over time to keep the original grade.

All filter strips should be inspected on an annual basis. Strips should be examined for damage by foot or vehicular traffic, encroachment, gully erosion, density of vegetation, and evidence of concentrated flows through or around the strip. Extra strip maintenance must be devoted in the first few months and years to make sure the strip becomes adequately established. This may involve extra watering, fertilization and reseeding.

DESIGN SUMMARY: FILTER STRIPS

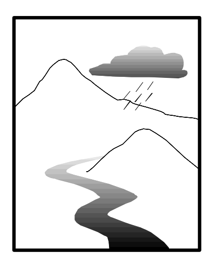
* **GRADING:**
The top edge of the filter strip should follow across the same elevational contour. If a section of the top edge of the strip dips below the contour, it is likely that runoff will eventually form a channel toward the low spot.

* **SPREADER:**
A shallow stone trench can be used as a level spreader at the top of the strip to distribute flow evenly. This also serves to protect the strip from man-made damage.

* **LENGTH:**
The appropriate length for filter strips is still the subject of some debate. As an absolute minimum, a grass strip should be at least 20 feet wide. Better performance can be achieved if the strip is 50 to 75 feet long, plus an additional 4 feet per each one percent of slope at the site (particularly if it is a forested strip).

* **VEGETATION:**
New buffer strips require the establishment of a dense layer of vegetation, including grasses, shrubs and trees. Successful establishment requires the selection of appropriate vegetation, proper seeded preparation and soil conditioning which may include the addition of topsoil. Planting vegetation during its regular growing season will increase the chances for success and may lessen the need for watering. Wooded filter strips are preferred to grassed strips. If an existing wooded belt cannot be preserved at the site, the grassed strip should be managed to gradually become wooded by intentional plantings.

* **SEDIMENT:**
If a filter has been used as a sediment control measure during the construction phase, it is advisable to regrade and reseed the top edge of the strip. Otherwise, the sediment trapped in the filter strip may effect the flow patterns across the strip, thereby reducing its effectiveness.



SECTION V

WATER QUALITY INLETS

You will need to consider installing advanced management practices if you have implemented all the recommended practices (BMPs in Supplement “A”) that are reasonable and economically feasible and still have not controlled pollutants sufficiently to meet your local discharge requirements.

If your facility exterior is a significant problem, you may need to pretreat the stormwater before discharge into the storm drain system. This section describes controls that are more extensive and, in general, may be more costly than other recommended practices in this manual. Advanced pollution control practices take a number of forms, and may include a wide range of solutions that are not listed here. You may develop other approaches that are more effective for your facility.

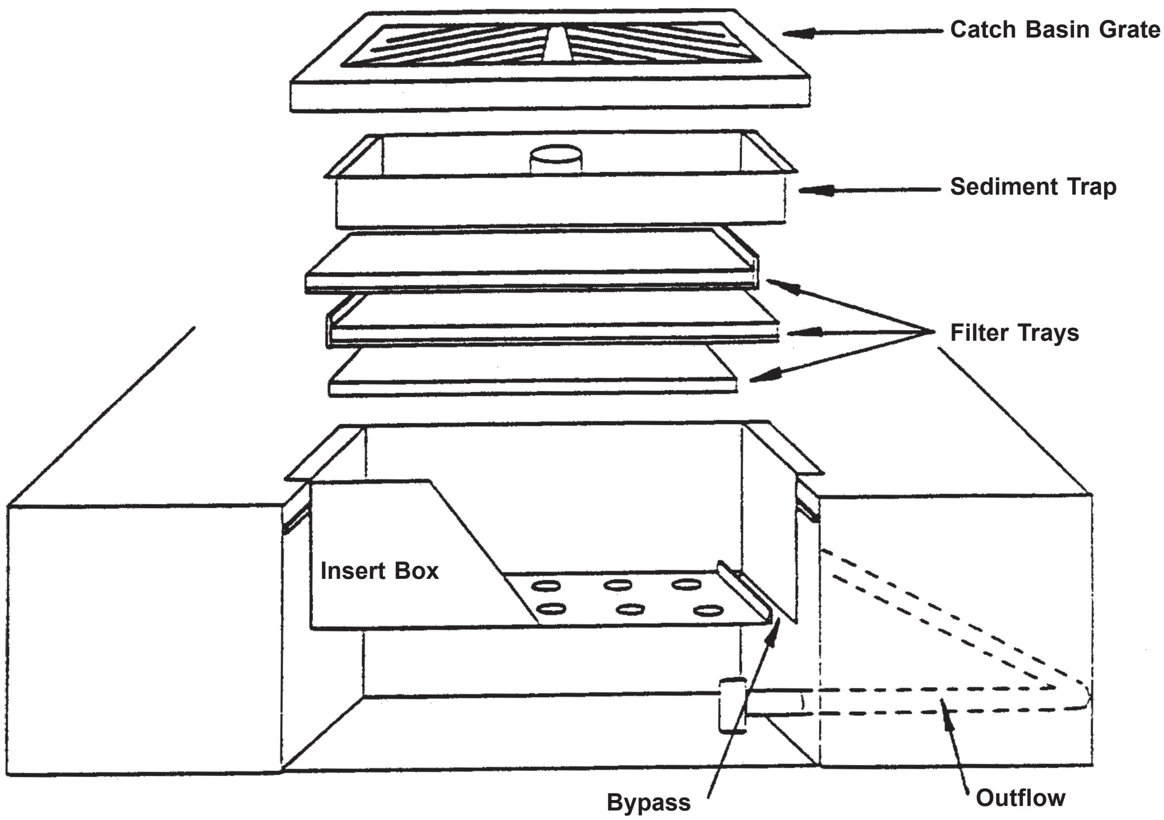
Storm drain filters is one type of pretreatment device that is generally the least expensive of these methods. As technology improves some of these devices are finding wide range acceptance. The more elaborate form of pretreatment device is the “water quality inlet”, also known as oil/grit separators. Water quality inlets have baffles, in a variety of configurations, to prevent oils and grease from flowing to the storm drain. The baffles remove the bulk of floating oily wastes, but do not remove oil as completely as a more sophisticated treatment process (e.g., oil skimmer, coalescing plate separator). Although many inlet design variations exist, two are presented here for information purposes; the conventional rectangular concrete chamber Montgomery County design and the Canadian “Stormceptor” design.

It should be noted that actual pollutant removal is accomplished when trapped residuals are cleaned out of the inlet. The greatest environmental concern is the pollutant toxicity of trapped residuals and oily waters, and how the toxicity influences the ultimate disposal of the residuals.

STORM DRAIN FILTERS

A storm drain filter is a storm drain inlet or catch basin that has a filtering device to prevent sediment, debris, oils, and grease from flowing through the system. Filters can be fitted to inlets in a variety of configurations (Figure 1). Most designs allow you to use any variety or combination of filter medium for site specific pollutants, adding to their versatility. Generally, these filters can accommodate large-quantity, short-duration flows, such as stormwater from a parking lot or working area. The pollutant removal capability of these systems have been reported as very promising. A relatively new and innovative product for typical catch basin openings is called the Fossil Filter (Figure 2). The Fossil Filter was designed to capture contaminates that normally enter inlets during low to medium flows and does not inhibit flow during high flows when drain capacity is critical.

FIGURE 1: Catch Basin Filter.



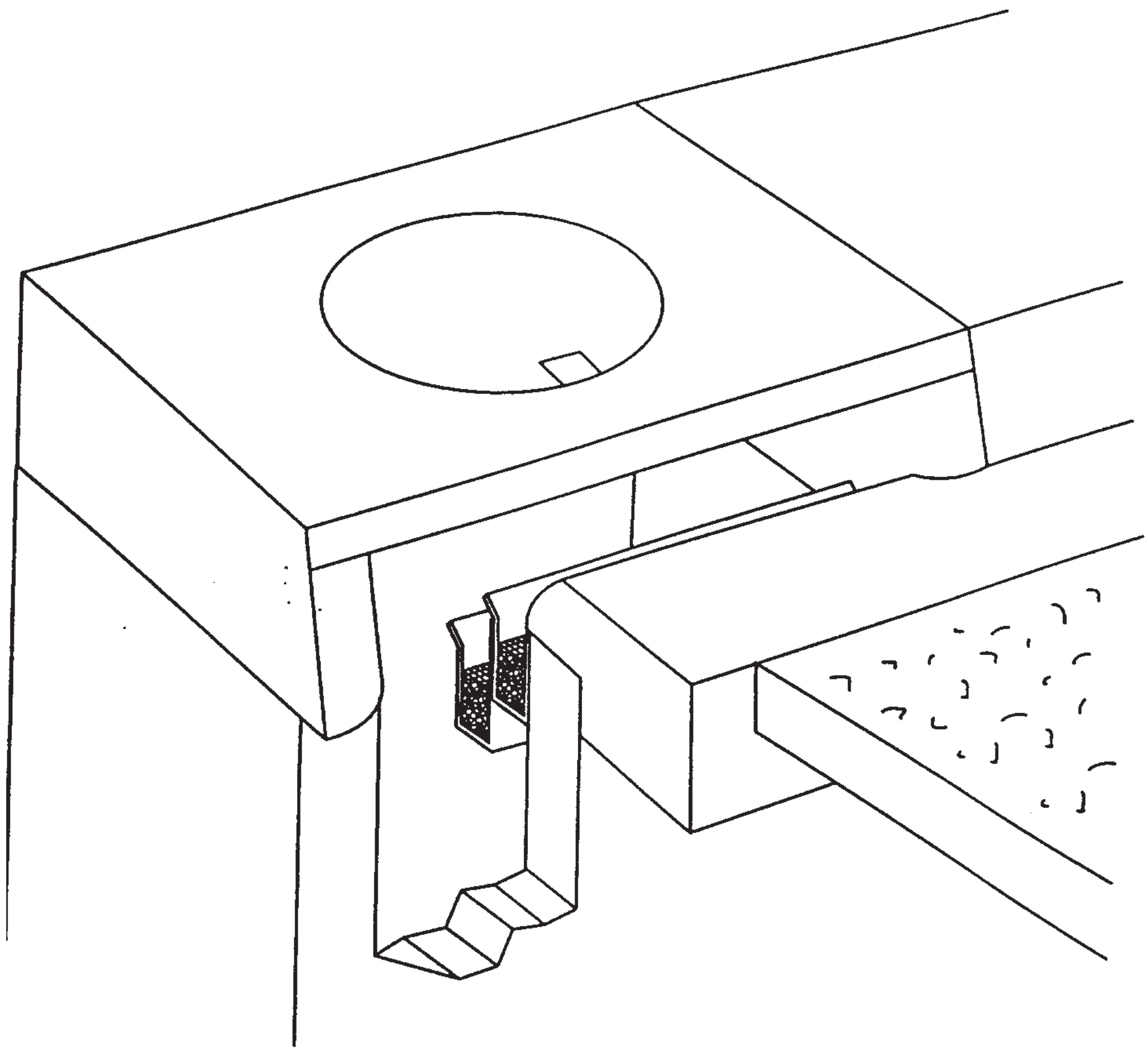
The following Manufacturers can be contacted for further information:

- **Auqa-Net, Inc., produces the "Gullywashers" line of vinyl coated, wire baskets for placement in storm drain and sewer inlets. Their toll free number is 800/208-5447.**

- **Enviro-Drain, Inc., produces a catch basin stormwater filter that uses a combination of filter mediums. Their number is 206/820-1953.**

FIGURE 2: Fossil Filter

The Fossil Filter has a trough area for retention of a removable and replaceable absorbent filter material in a filter cartridge. With the filter cartridge, this trough will allow water to flow unimpeded while removing undesirable and toxic materials that may be carried in the water. The Fossil Filter is designed to be adjusted to fit the numerous sizes of square or rectangular drainage inlets such as flat grated type inlets, curb opening type inlets, and combination curb opening and gutter grate type inlets.



For more information on this product please contact KriStar Enterprises, Inc., at 800-579-8819.

CONVENTIONAL WATER QUALITY INLET

Under current designs, conventional water quality inlets only store a small fraction of the two year design storm volume, and because of their limited capacity, these inlets play no role in modifying the post development peak discharge rate. The pollutant removal capability of these inlets has never been monitored in the field[1]. However, since runoff is only briefly retained in the inlets, only moderate removal of coarse sediment, oil/grease, and debris can be expected. Even more limited removal is likely for fine-grained particulate pollutants such as silt, clay and associated trace metals and nutrients. Soluble pollutants probably pass through inlets without modification. These inlets typically serve parking lots one acre or less in size, and sites that are expected to receive a great deal of vehicular traffic or petroleum inputs (e.g., gas stations, roads, loading areas).

Routine maintenance costs are high since the inlets must be cleaned out regularly to retain their effectiveness and to avoid spilling oily wastes. The collected oils and grease should be removed at least monthly, and disposed of as hazardous waste. Remove oils and grease more often during the rainy season so that heavy rainfall does not wash the pollutants through the trap into the drain.

Advantages of the water quality inlets lie in their unobtrusiveness, compatibility with the storm drain network, easy access, and capability to pretreat runoff before it enters infiltration BMPs. Disadvantages include their limited stormwater and pollutant removal capabilities, the need for frequent clean-outs (which cannot always be assured), and possible difficulties in disposing of accumulated sediments.

Montgomery County Design

A typical three chamber design for a water quality inlet, developed in Montgomery County, Maryland (MCDEP, 1984b), is shown in Figure 3. Basically, the inlet is a long rectangular concrete chamber connected to the storm drain system. Runoff passes through three chambers that are specifically modified to separate out sediment, grit and oil before exiting through a storm drain pipe.

The first chamber in the inlet contains a permanent pool of water that is three to four feet deep, and is connected to the second chamber by a pair of well-screened six inch holes. The first chamber is used for gravity settling of grit and sediments, and can also trap floatable debris, such as leaves and litter.

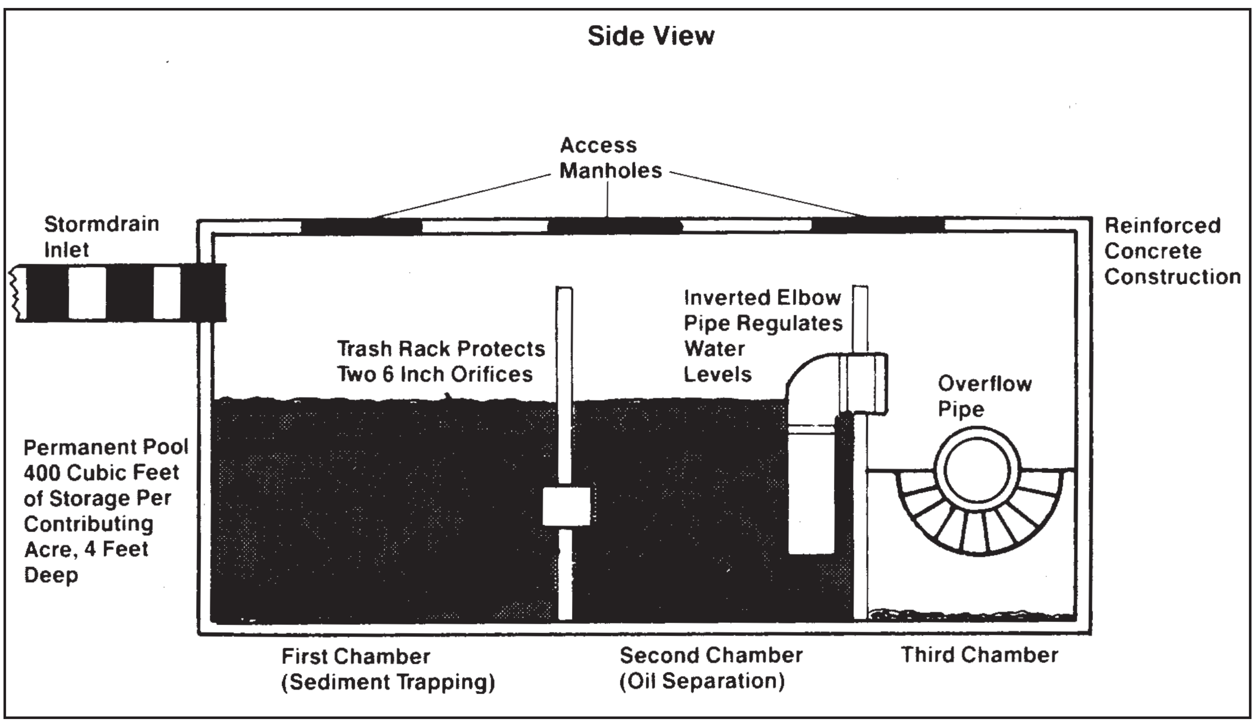
[1] The Metropolitan Washington Council of Governments has conducted a long-term study to provide data on many unknowns about water quality inlets. Their April 1993 report on Oil-Grit Separators should be considered before a design is selected.

The second chamber also holds a permanent pool of water. An inverted pipe elbow leads to the third chamber which regulates water levels in the inlet. Runoff must pass through the bottom opening of the inverted pipe, and then travel upward several feet before it enters the third chamber. This design feature discourages clogging, and more importantly, traps oil and gas films floating on the surface in the second chamber. Oil and gas films remain in the second chamber until they are gradually absorbed by sediment particles and settle out.

The third chamber contains a brick cradle that forms an opening to a storm drain outlet pipe. If the cradle is elevated from the floor of the chamber, a third permanent pool is created that may become an additional site for settling. Otherwise, the third chamber has little value in pollutant removal.

Water quality inlets are sized to provide 400 cubic feet of wet storage per contributing acre, and a pool at least four feet deep. Additional dry storage must also be provided to pass the design storm. Access to each chamber for inspections and regular clean out is provided by a separate manhole cover and step rings. Design criteria is summarized on the next page.

FIGURE 3: Schematic of a Water Quality Inlet, Montgomery County, MD. Three Chamber Design



DESIGN SUMMARY: CONVENTIONAL WATER QUALITY INLET

* **AREA SERVED:**
  Inlets typically serve impervious areas of less than one acre.

* **PERMANENT POOL:**
  The volume of the permanent pool should be maximized. At least 400 cubic feet of wet storage per impervious acre is suggested as an initial sizing rule. The permanent pool in each chamber of the inlet should be at least four feet deep.

* **CLEAN-OUT SCHEDULE:**
  Accumulated sediment should be cleaned out from inlets at least twice per year. This can be done by vacuum pumping or siphoning of the permanent pool, and annually removing sediment deposits.

* **DISPOSAL METHODS:**
  Disposal options for the sediment will probably range from disposal in a works yard to disposal in a sanitary landfill site (the sediment should be tested to determine the disposal options). Hazardous materials collected in the inlet (oil/chemical/fuel spills) should be removed by a licensed waste management company and disposed of accordingly. Runoff in the inlet can be siphoned over to an adjacent grass filter strip, or transported to a sanitary sewer line and routed to a treatment plant.

* **PREVENTING RESUSPENSION:**
  Resuspension of deposited pollutants can be a problem in inlets. The use of vertical baffle plates on chamber floors may help alleviate this problem. Also, the floor of each chamber should slope slightly away from the outlet to the next chamber.

* **INVERTED ELBOW:**
  An inverted pipe with a 90 degree elbow should connect the second and third chambers of the inlet. The elbow can be formed by welding two cut sections of aluminized CMP, and the vertical portion should extend to one foot from the bottom of the inlet.

* **USE WITH UNDERGROUND INFILTRATION:**
  Inlets can be used to pretreat runoff before it enters an underground infiltration facility (e.g., porous pavement or an infiltration trench).

* **CLOGGING:**
  The two 6-inch orifices that lead from the first to the second chamber should be screened by a half round of aluminized CMP, in which ½-inch holes have been drilled.

* **ACCESS:**
  To facilitate clean-outs, access to each chamber should be provided by means of a separate manhole and step rings.

CANADIAN STORMCEPTOR

The Stormceptor is a pollution prevention device developed in Canada that removes oil and sediment from stormwater. The unit can replace a conventional manhole in the storm drain system.

The key advantage to the Stormceptor compared to other water quality controls in a storm drain is the bypass which prevents the resuspension and scour of settled material during subsequent storm events. The Stormceptor storage chamber is air tight so that any volatile petroleum products which are trapped by the interceptor are not released into the atmosphere. The device is applicable in a variety of development situations including:

* stormwater quality retrofits for existing development
* industrial and commercial parking lots
* automobile service stations
* airports
* areas susceptible to spills (of materials lighter than water), (bus depots, transfer stations, etc.)
* new residential developments (as part of a treatment train)
* re-development in the urban core

Design and Operation

The Stormceptor can be divided into two components: treatment chamber and the by-pass chamber. Stormwater flows into the by-pass chamber via the storm drain pipe. Low flows are diverted into the treatment chamber by a weir and drop pipe arrangement (Figure 4). The drop pipe is configured to discharge water tangentially along the treatment chamber wall. Water flows through the treatment chamber to the outlet pipe which is submerged similar to the drop inlet pipe. Water flows up through the outlet pipe based on the head at the inlet weir, and is discharged back into the by-pass chamber downstream of the weir. The downstream section of the by-pass chamber is connected to the outlet storm pipe.

Oil and other liquids with a specific gravity less than water will rise in the treatment chamber and become trapped since the outlet pipe is submerged. Sediment will settle to the bottom of the chamber by gravity and centrifugal forces. The circular design of the treatment chamber prevents turbulent eddy currents and promotes settling.

During high flow conditions, stormwater in the by-pass chamber will overtop the weir and be conveyed to the outlet sewer directly (Figure 5). Water which overflows the weir creates a backwater effect on the outlet pipe (head stabilization between the inlet drop pipe and outlet riser pipe) ensuring that excessive flow will not be forced into the treatment chamber which could scour or resuspend the settled material.

FIGURE 4: Stormceptor Operation During Average Flow Conditions

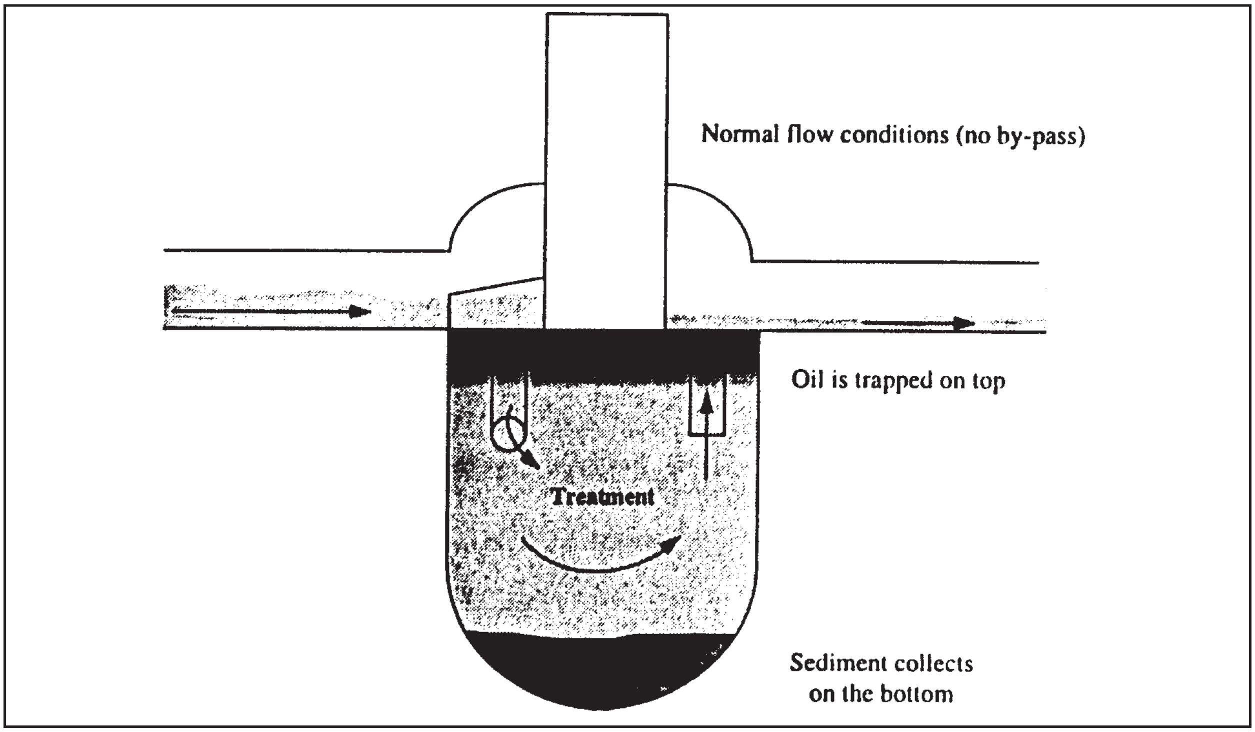
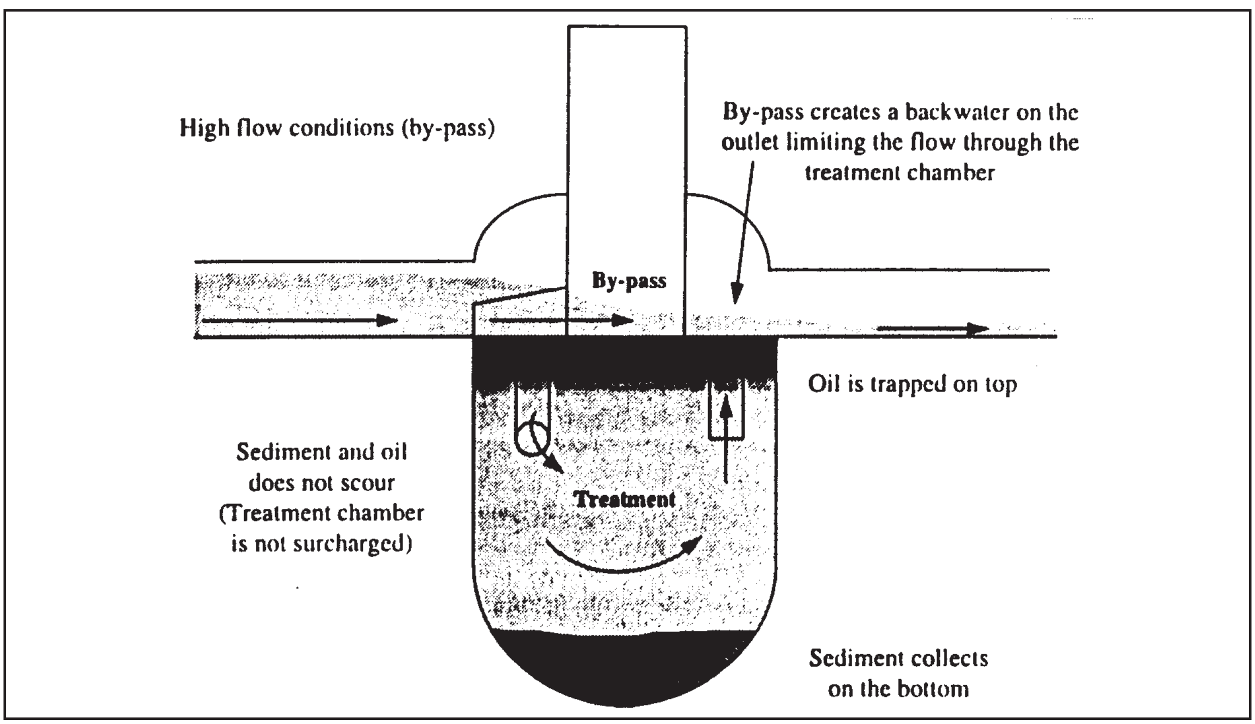


FIGURE 5: Stormceptor Operation During High Flow Conditions



Construction Material

The Stormceptor is manufactured in both fiberglass and concrete. Stormceptor Canada, Inc., manufactures fiberglass interceptors in its Mississauga, Ontario plant. Current interceptor sizes being manufactured range from 108 to 1,000 cubic feet (6 foot to 12 foot diameter interceptors).

Hydroconduit, Carder Concrete, and Wyoming Concrete manufacture the precast concrete Stormceptor in the United States under license to Stormceptor Corporation. The same sizes of interceptors are manufactured in concrete as well as in fiberglass.

Maintenance

Maintenance of the Stormceptor is performed using vacuum trucks. Costs to clean the Stormceptor vary based on the size of the unit, transportation distances and disposal.

Although annual maintenance is recommended, adequate data on the maintenance of Stormceptor units is not available. Accordingly, it is recommended that annual maintenance be performed initially, and that the frequency of maintenance be adjusted based on the local conditions (i.e., if the unit is filling up with sediment more quickly than projected, maintenance may be required semi-annually; conversely, once the site has stabilized maintenance, may only be required once every two years).

If the Stormceptor is implemented in areas where the potential for spills is great, the unit should be cleaned immediately after a spill occurs. Appropriate regulatory agencies should also be notified in the event of a spill.

Requirements for the disposal of material from the Stormceptor is similar to that of any other BMP (the sediment should be tested to determine the disposal options). Disposal options for the sediment will probably range from disposal in a works yard to disposal in a sanitary landfill site. Hazardous materials collected in the Stormceptor (oil/chemical/fuel spills) should be removed by a licensed waste management company and disposed of accordingly.

APPENDIX A

SCREENING FACTORS

SCREENING BMPs BASED ON PHYSICAL SUITABILITY

The nature of each of the physical factors outlined in the screening tools is described below.

Watershed Area Served

Pond[1] BMPs normally require a significant contributing watershed area (greater than ten acres) to ensure proper operation. The lower range of suitability for ponds is set by the minimum orifice size for dry extended detention ponds. By contrast, infiltration and vegetative BMPs are generally only applicable on sites less than ten acres, due to space, economic or flow velocity constraints.

It should be noted that the contributing area of a site does not always have to be fixed. By creatively using local topography and drainage, site area can be increased or decreased to better accommodate a particular BMP. For example, additional runoff generated away from the site (off-site runoff) can be routed to the BMP, thereby increasing total site area and making pond options more feasible. Conversely, various portions of the total runoff from a site can be routed to individual BMPs (decreasing site area, and making infiltration and vegetative BMPs more practical).

Soil Type

The permeability of the soil underlying a BMP has a profound influence on its effectiveness. This is particularly true for infiltration BMPs, which should not be applied on sites with soils that have infiltration rates less than 0.27 inch/hour (Source: MNPCA, 1991), as defined by the least permeable layer in the soil profile. This excludes most "C" and "D" soils (Soil Conservation Service Classification System) which cannot exfiltrate enough runoff through the subsoil. Pond BMPs tolerate a much broader range of soil conditions. Extremely permeable sandy soils may make it difficult to maintain water levels in wet ponds, and clayey soils may cause standing water problems in dry extended detention ponds.

Slope

Steep slopes restrict the use of several BMPs. For example, porous pavement and grassed swales must be situated in sites with slopes of 5% or less. Also, infiltration trenches and filter strips are not practical when slopes exceed 20%.

High Water Table

The water table acts as an effective barrier to exfiltration and can sharply reduce the ability of an infiltration BMP to drain properly. If the height of the seasonally high water table extends to within four feet of the bottom of an infiltration BMP, the site is seldom considered suitable.

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[1] Ponds require a permanent pool of water for treating incoming stormwater runoff, thus they were not addressed in this document due to our arid western climate.

Proximity to Foundations and Walls

Since infiltration BMPs divert runoff back into the soil, some sites may experience problems with local seepage. This can be a real problem if the BMP is located too close to a building foundation. Another risk is that the runoff and pollutants diverted into the groundwater may contaminate water supplies. While relatively little research has been performed to evaluate this risk, it is advisable to keep infiltration BMPs located at least 100 feet away from drinking water wells.

Land Consumption

Some sites are so small or so intensively developed that no room is available for BMP options that consume a large amount of space. Pond BMPs and porous pavement both require a large surface area and a generous buffer, and, consequently, may not fit into extremely tight sites.

Maximum Depth

To preserve storage capacity and provide optimal pollutant removal conditions, infiltration BMPs must be designed to completely drain within 2 to 3 days after a storm. If the infiltration rates of the underlying soils are marginal, the depth of the infiltration facility may be limited. These restrictions vary depending on whether the facility is a trench, basin or porous pavement.

Restricted Land Uses

Certain BMPs can only be applied to particular land uses, and are not broadly applicable for all development sites. Porous pavement, for example, can only be used for sites with parking lots not expected to receive heavy car or truck traffic. Similarly, grassed swales can only be used in conjunction with low density residential areas or roads.

High Sediment Input

Most BMPs are unable to handle the large loads of sediment eroded during the construction phase of development. Infiltration BMPs are particularly susceptible to rapid clogging and subsequent failure if significant sediment loads are allowed to enter the structure. As a general rule, these BMPs should not be installed until all of the land disturbed by construction in the contributing watershed is effectively stabilized. Contractors must often take unusual steps during the actual installation of the infiltration BMPs to prevent soil compaction or sediment contamination. To prevent clogging of infiltration BMPs after construction, many designs call for the use of a pre-treatment device to filter out sediment and other coarse particles before they reach the facility.

Stream Warming

Shallow marshes and wet ponds warm up rapidly during the Summer months. Under certain circumstances, runoff leaving these BMPs can be 5 to 10 degrees warmer than the runoff entering the structure. Such warm water release can be a lethal thermal shock to aquatic organisms that are adapted to cold water conditions. Thus, the use of wet ponds and shallow marshes should be avoided in watersheds with sensitive cold-water streams.

SCREENING BMPs BASED ON STORMWATER BENEFITS PROVIDED

Urbanization tends to increase runoff and pollutant loadings to the receiving water body. The most effective runoff quality controls reduce the runoff peak and volume. Consideration involves a number of factors:

Peak Discharge Control

Some local regulations require that a nonpoint source control method be able to control the peak flow from a two year storm (a storm expected to produce a flood every two years). Some jurisdictions require control of even larger storms. Ponds are an excellent method for achieving this goal; infiltration basins are somewhat less effective. Even if a BMP does not control these larger design storms, they must still be designed to safely pass them through (e.g., using an emergency spillway or overflow pipe).

Control of First Flush

First flush is the disproportionately large amount of pollutants usually found in runoff during the early part of a high intensity or large volume storm, caused by the rapid runoff of accumulated pollutants. First flush control - the first ½ inch of rainfall - can also be required for a runoff area. However, if storms in an area are frequent, the first flush may not be significant and further monitoring may be needed.

Volume Control

Infiltration BMPs can help to reduce the increased runoff volumes generated from small and intermediate storms, since they divert a significant fraction of storm runoff volume back into the soil. Pond BMPs, on the other hand, are ineffective in reducing runoff volume. Ponds only detain or retain runoff for a short period of time before releasing it downstream.

Ground Water Recharge

Infiltration BMPs provide an excellent way to replenish groundwater lost because of development; however, this benefit must be weighed against the potential for groundwater contamination.

Streambank Erosion Control

While some nonpoint source pollution methods control streambank erosion to some extent during a two year storm if properly designed, installed, and maintained, more severe storms require large extended detention ponds and infiltration controls to prevent downstream erosion.

SCREENING BMPs BASED ON POLLUTANT REMOVAL BENEFITS

The nature of the pollutant being removed often sets an upper limit on the potential removal rate that can be achieved. From an operational standpoint, pollutants can be said to exist in either particulate or soluble forms, or more commonly, as a mix of both forms. Particulate pollutants, such as sediment and lead, are relatively easy to remove by common BMP removal mechanisms, including settling and filtering. Soluble pollutants, such as nitrate, phosphate, and some trace metals, are much more difficult to remove. Settling and filtering removal mechanisms have little or no effect, and biological mechanisms, such as uptake by bacteria, algae, rooted aquatic plants or terrestrial vegetation, must be used.

SCREENING BMPs FOR ENVIRONMENTAL AMENITIES

Local governments should consider the total environment in selecting a nonpoint source pollution strategy that will provide the maximum benefit to the environment and to consumers. These benefits usually depend not only on the method itself but also on its design, maintenance, and congruence with the surrounding landscape.

Low Flow Maintenance

Downstream aquatic life can be jeopardized when the natural low flow levels experienced during the Summer months decline even further because of reduced infiltration in urbanized watersheds. Infiltration BMPs contribute significantly to groundwater recharge and appear to be capable of sustaining low flows during the critical Summer months if widely applied in a watershed. Vegetative BMPs, such as swales and filter strips, appear to have modest potential in this regard, and pond BMPs have little effect in maintaining low flows.

Streambank Erosion Control

Streambank erosion not only contributes large sediment loads to receiving waters, but also has an adverse impact on the habitat quality for downstream aquatic life. Some BMPs, such as extended detention ponds and full exfiltration BMPs, can control erosive storm flows enough to keep downstream channels and banks relatively stable, whereas most other BMPs have only marginal capabilities.

Aquatic Habitat Creation

Some BMP options are attractive in that they can create wetland or open water areas utilized by waterfowl, marsh birds, and other wildlife. Shallow marshes and wet ponds are particularly well suited for this role, if relatively small investments are made in landscaping design and plant selection. “Volunteer” wetland plants may also colonize these BMPs (and poorly drained extended detention ponds) without intentional planting efforts, but may not provide high quality habitat.

Wildlife Habitat Creation

BMPs with generous buffers (wet ponds, extended detention ponds, infiltration basins and filter strips) present good opportunities for creating terrestrial wildlife habitat. The buffer areas (and sometimes the basin floors) can be managed as wet meadows, thus reducing mowing costs for the facility. Relatively diverse biological communities can be further enhanced through judicious planting of trees, shrubs and grasses that provide food and cover for wildlife. These communities have added value because of the general scarcity of wildlife habitat in urbanized areas.

No Thermal Enhancement

As noted earlier, wet ponds can be detrimental in some watersheds as they heat water passing through the structure during the Summer months. Their use is often restricted in watersheds that contain sensitive cold-water fisheries, such as those that support native trout populations.

Landscape Enhancement

Few BMPs will be an attractive feature of a community unless serious efforts are directed toward natural grading, landscaping and regular maintenance. If properly designed, pond options probably have the most potential to enhance the urban landscape. Wet ponds are frequently used to create a waterfront effect in residential developments, and may actually increase the value of adjacent property. Vegetative BMPs have a less dramatic effect on landscape values, and most infiltration BMPs and dry extended detention ponds have a neutral or negative effect.

Recreational Benefit

With the exception of large wet ponds, few BMPs provide active recreational opportunities (e.g., fishing, swimming, or skating). In fact most jurisdictions generally do not encourage such activities, as they may invite vandalism or liability problems. However, if properly landscaped, pond BMP options can provide passive recreation opportunities for adjacent residents such as walking, bird watching, or nature enjoyment, particularly when combined with bike or jogging paths, picnic areas, and tot-lots situated in nearby open space. In rare instances, the floors of extended detention ponds can even be used for ball fields and play areas.

Hazard Reduction

Careful design of pond BMPs is needed to reduce potential safety hazards. Plans should be analyzed to eliminate obvious hazards, such as steep side-slopes, deep water, sudden drop-offs from the shore, or dangerous outlet/pipe configurations. Most infiltration BMPs entail little if any safety risks, and some (porous pavement) are thought to reduce certain traffic safety problems.

Aesthetic Value

As shown in Table 2, most pond options have the potential to be either an attractive or an unattractive feature of a community, depending on the attention paid to their design, landscaping, and maintenance. Artificial contours should be avoided, and control structures (risers, low flow channels, outlets and riprap) should be concealed in the embankment, or by vegetation when feasible. Infiltration BMPs generally have little potential to be attractive, but can at least be designed to be unobtrusive.

Community Acceptance

Survey of resident perceptions about adjacent BMPs have revealed that most BMPs are acceptable if regular cosmetic maintenance is performed. Residents often indicate a preference for wet ponds over dry ponds. Their response to infiltration BMPs is not well documented. Residents' primary concerns often center around perceived nuisance conditions (algae blooms, odors, mosquitoes, weeds, trash, turbidity, etc.), most of which are temporary conditions which should seldom occur if the BMP is properly designed and maintained.

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