MINIMUM STANDARD 3.10

GENERAL INFILTRATION PRACTICES

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MINIMUM STANDARD 3.10

GENERAL INFILTRATION PRACTICES

Definition

Infiltration facilities temporarily impound stormwater runoff and discharge it via infiltration into the surrounding soil.

Purpose

Infiltration facilities are primarily used for water quality enhancement. Their use to control large volumes of runoff for flooding and channel erosion control is often impractical. Therefore, the infiltration facilities presented in this handbook should generally be used to control the water quality volume and up to the 2-year design storm only. Infiltration practices that capture all of the runoff from the "first flush" (i.e., the water quality volume) may utilize dry storage above the water quality volume to provide sufficient reductions in the 1- or 2-year peak discharge as required. The 10-year and 100-year flows will usually exceed the capacity of an infiltration facility. **Table 3.10-1** contains the target pollutant removal efficiencies based on the runoff volume to be controlled.

Infiltration practices are appealing in that they help to reverse the hydrologic consequences of urban development by reducing peak discharge and providing groundwater recharge.

TABLE 3.10 - 1
Pollutant Removal Efficiency for Infiltration Facilities

BMP Description	Target Phosphorus Removal Efficiency
Infiltration facility with storage volume equivalent to 0.5 inches of runoff from the impervious Area.	50%
Infiltration facility with storage volume equivalent to 1.0 inch of runoff from the impervious area.	65%

FIGURE 3.10 - 1a

Infiltration Basin - Plan and Section

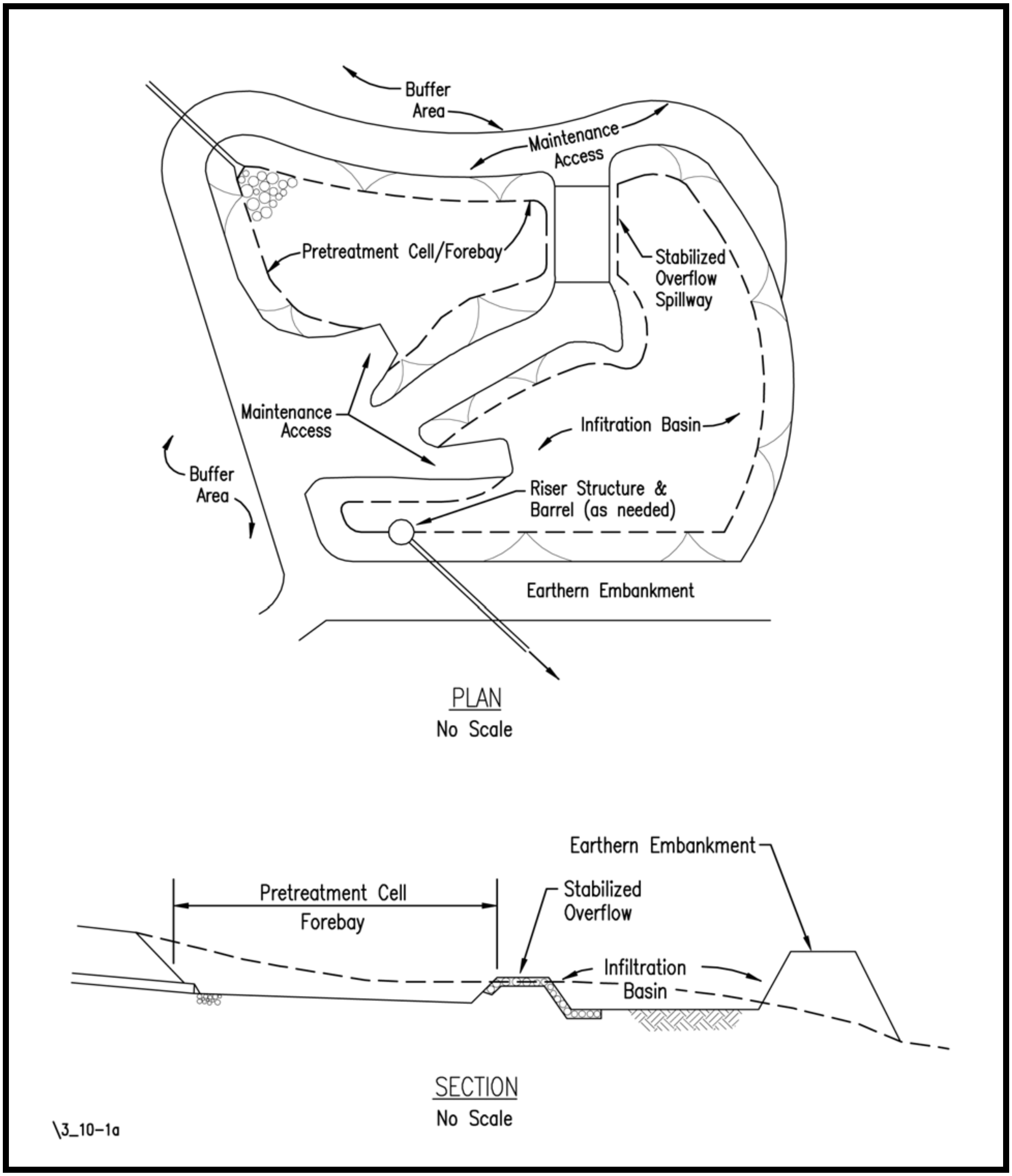
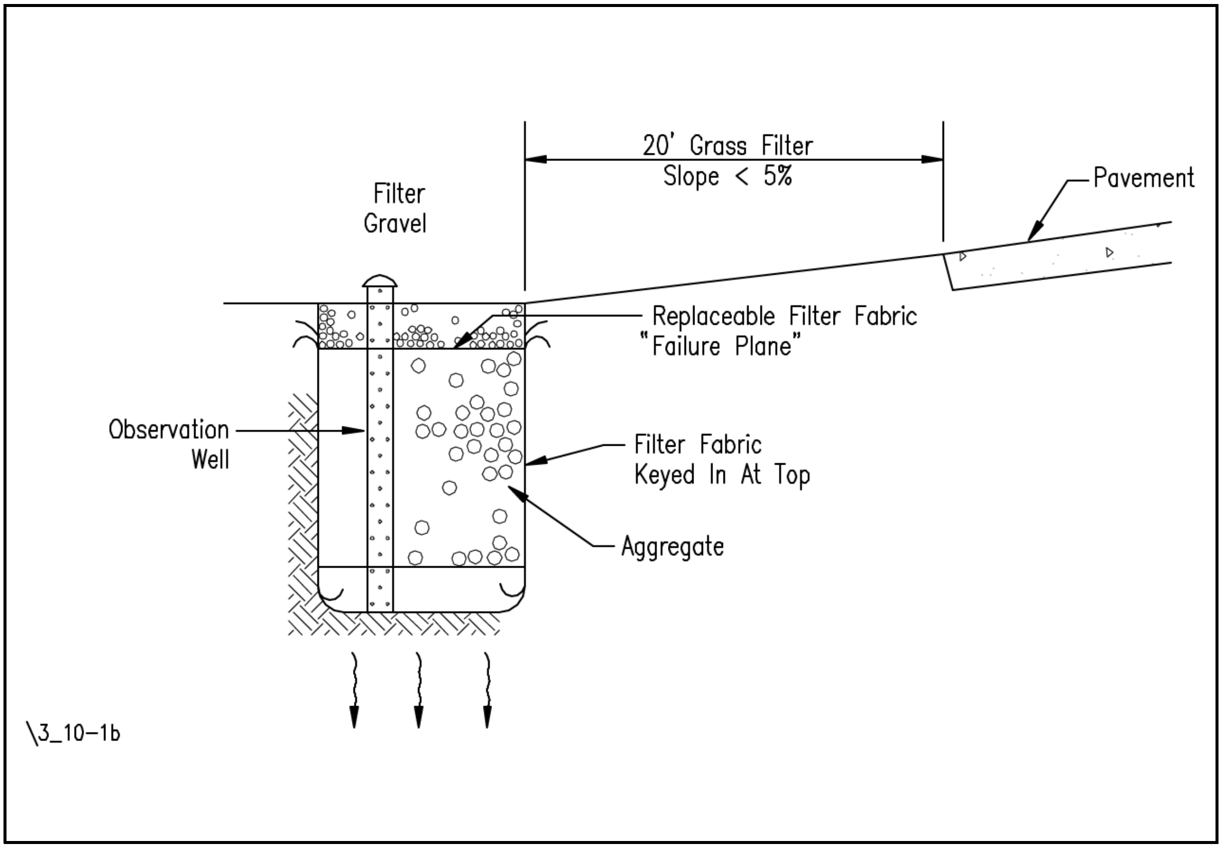


FIGURE 3.10 - 1b
Infiltration Trench - Section



Conditions Where Practice Applies

Infiltration facilities are suitable for use where the subsoil is sufficiently permeable to provide a reasonable rate of infiltration. They are also practical where the water table is sufficiently lower than the design depth of the facility to prevent pollution of the groundwater. Infiltration is not recomended for areas underlain by karst topography. Concentrating runoff into an infiltration facility may cause solution channels to develop or cause karst collapse.

Infiltration practices are generally suited for low- to medium-density development (38% to 66% impervious cover). Specific conditions such as drainage area size and development conditions for each infiltration practice are discussed in the appropriate section of this Standard.

Infiltration facilities are subject to clogging and, therefore, are not recommended for areas where sediment, grease, or oil loadings may be high. Such areas include roadways, parking lots, car service facilities, etc. To increase the life expectancy of an infiltration facility, a pretreatment facility such as a settling basin or "cell", or additional BMP in series should be used to remove sediments or other substances from the stormwater runoff **before** it enters the infiltration facility. Refer to **Minimum Standard 3.15, Manufactured BMP Systems** for additional pretreatment BMPs.

Planning Considerations

The following planning considerations are provided for infiltration practices overall. More specific considerations that may be applicable are presented with each infiltration practice.

Site Conditions

In the past, many designs were accepted based on soils information compiled from available data, such as SCS soil surveys. While these sources may be appropriate for a pre-engineering feasibility study, final design and acceptance should be based on an actual subsurface analysis and permeability tests.

The high failure rates of infiltration facilities, as presented in recent studies (MWCOG), suggest that site-specific soil borings should be required to support the use of infiltration practices. The suitability of the soil for use with the desired infiltration practice can be determined from the soil boring analysis. Details for appropriate geotechnical techniques can be found in the references listed at the end of this section (MD WRA). In general, the following information should be included in a site-specific subsurface or geotechnical study:

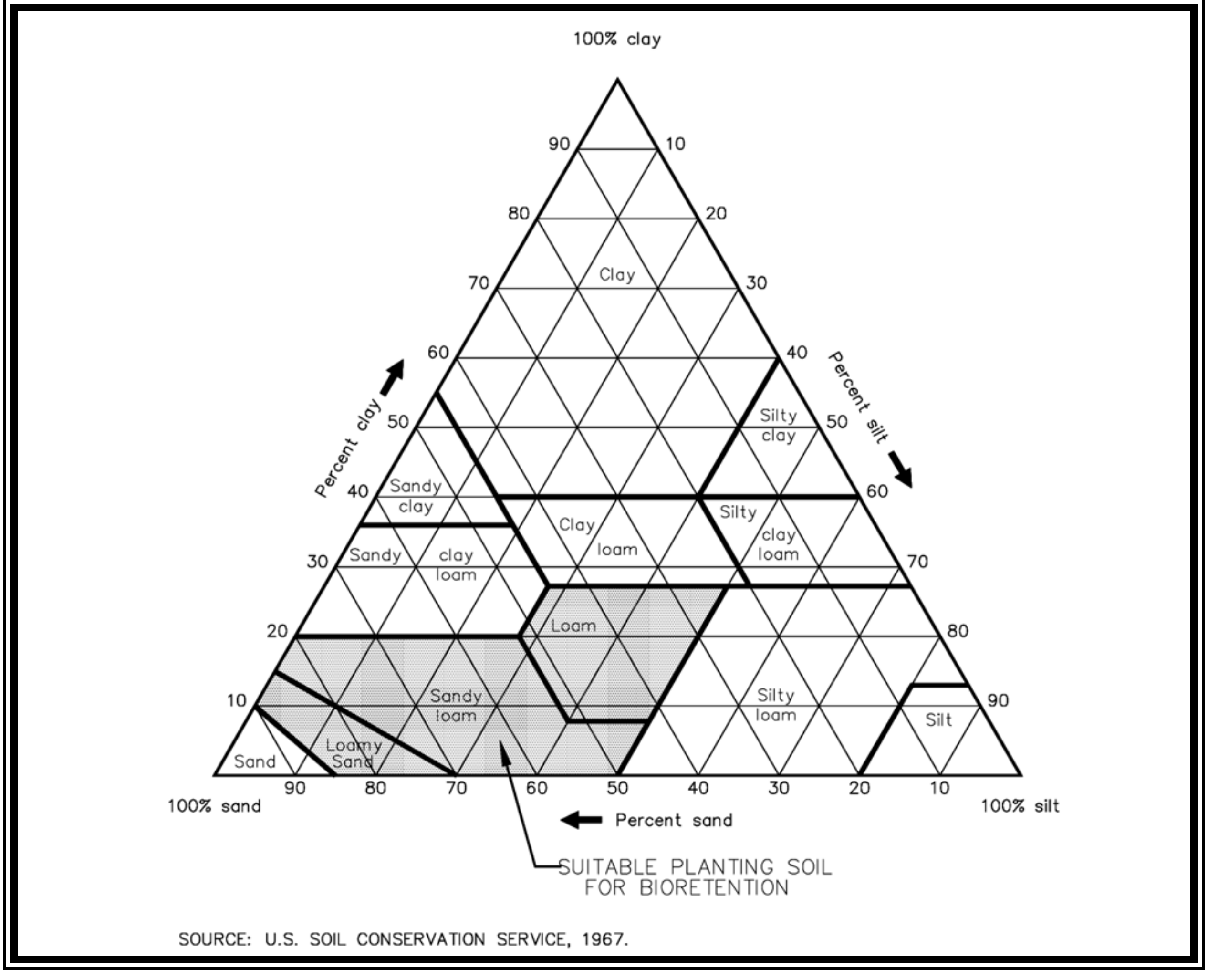
1. **Soil permeability**

   The soil types within the subsoil profile, extending a minimum of 3 feet below the bottom of the facility, should be identified to verify the ***infiltration rate*** or ***permeability*** of the soil. The infiltration rate, or permeability, measured in inches per hour, is the rate at which water passes through the soil profile during saturated conditions. Minimum and maximum infiltration rates establish the suitability of various soil textural classes for infiltration. Each soil texture and corresponding hydrologic properties within the soil profile are identified through analysis of a gradation test of the soil boring material. **Soil textures acceptable for use with infiltration systems include those with infiltration rates between 0.52 inches per hour and 8.27inches per hour, and include loam, sandy loam, and loamy sand**.

Soil textures with infiltration rates ***less than 0.52 inches per hour*** *or greater than* ***8.27 inches per hour*** *are* ***not suitable*** *for infiltration practices.*

FIGURE 3.10 - 2

USDA Textural Triangle



SOURCE: U.S. SOIL CONSERVATION SERVICE, 1967.

Soils that have a 30% clay content are unacceptable for use with infiltration facilities since they are structurally unstable and susceptible to frost heaving. Similarly, soils that have poor percolation capabilities or excessively drained soils, such as sand, should not be used for infiltration purposes. The soil textures presented in **Table 3.10-2** correspond to the soil textures of the U.S. Department of Agriculture (USDA) Textural Triangle presented in **Figure 3.10-2**. It should be noted that the difference in soil textures of sand and loamy sand are the percentages of clay found in the soil. While the actual percent of difference is small, a significant difference in infiltration rates can be expected. Note that actual permeability tests may indicate infiltration rates different from those in **Table 3.10-2**.

Predicting the exfiltration of water from an infiltration facility is difficult, especially over an extended period, such as the desired life expectancy of the facility. A factor of safety should be applied in the design to ensure that the facility is sized to function even when partially clogged. (This is discussed further in the **General Design Criteria** presented later in this section.)

TABLE 3.10 - 2

Hydrologic Soil Properties Classified by Soil Texture

Texture Class	Effective Water Capacity (C_w) (inch per inch)	Minimum Infiltration Rate (f) (inch per hour)	Hydrologic Soil Grouping
Sand	0.35	8.27	A
Loamy Sand	0.31	2.41	A
Sandy Loam	0.25	1.02	B
Loam	0.19	0.52	B
Silt Loam	0.17	0.27	C
Sandy Clay Loam	0.14	0.17	C
Clay Loam	0.14	0.09	D
Silty Clay Loam	0.11	0.06	D
Sandy Clay	0.09	0.05	D
Silty Clay	0.09	0.04	D
Clay	0.08	0.02	D

2. **Depth to the seasonal high groundwater table and bedrock**.

Typically, infiltration facilities are not recommended in areas with a high groundwater table due to the inability of the soil to adequately filter out pollutants before the stormwater enters the water table. A distance of **2** to **4** feet is required between the bottom of an infiltration facility and the existing water table or bedrock. Similarly, infiltration facilities are not recommended for areas where karst topography is present (in Virginia, west of the Blue Ridge Mountains) due to the possibility of causing subsurface collapse and sink hole formation.

Determination of the seasonal high groundwater table elevation should be given a high priority because flooding of an infiltration facility will render it inoperable during periods of high precipitation. Occasionally, based on the hydraulic conductivity of the soil and the physical dimensions of the trench, a <u>greater</u> separation than 2 to 4 feet may be necessary. Since some soils do not always contain the low chroma (gray) mottles indicative of seasonal saturation, an observation well may be used to locate the seasonal high groundwater table to verify the soil analysis.

Subsurface analysis techniques and related engineering recommendations are too broad and complex for the scope of this handbook. The references listed at the end of this section are recommended for further reading if more detailed information regarding the feasibility analysis of subsurface conditions is needed.

Selecting the optimum depth of an infiltration facility is a process of analyzing constraints. It includes seeking those soil horizons which have a permeability rate that will allow the structure to empty within 48 hours after a design storm event. The design elements of this process are covered in **General Design Criteria**, presented later in this section.

3. **Topographic conditions**

The topographic conditions of a development site represent feasibility factors that should be examined before designing an infiltration system. These factors include the slope of the land, the nature of the soil (natural or fill), and the proximity of building foundations and water supply wells.

The use of a particular BMP is restricted by the allowable slope for that practice. Porous asphalt pavement, for example, requires a relatively level or gently sloping area less than or equal to 3% (20H:1V). All other infiltration practices should be located in areas in which the slope does not exceed 20% (5H:1V). Using infiltration practices on a steep grade increases the chance of water seepage from the subgrade to the lower areas of the site and reduces the amount which infiltrates.

Developments occurring on sloping and rolling sites often require extensive cut and fill operations. The use of stormwater management infiltration systems on fill material is not recommended due to the possibility of creating an unstable subgrade. Fill areas can be very susceptible to slope failure due to slippage along the interface of the in-situ and fill material. This condition could be aggravated if the fill material is allowed to become saturated by using infiltration practices.

Nearby building foundations should be at least 10 feet up-gradient of the infiltration system to prevent the possibility of flooding basements. Proximity to septic systems is also a concern and local health officials should be consulted for guidance on minimum setbacks. Additionally, the location of infiltration practices should be a minimum of 100 feet from any water supply well where the runoff is from commercial or industrial impervious parking areas.

Sediment Control

It has been reported that many infiltration BMPs have failed because adequate precautions to prevent sediment contamination were not implemented (NVPDC, MWCOG). Provisions for long-term sediment control, or pretreatment of the stormwater runoff, must be incorporated into the design, along with precautions taken during onsite construction activities. Advance consideration should be given to the potential impacts that construction techniques, work sequence, and equipment could have on the future maintenance requirements of the BMP. Serious maintenance problems can be averted, or reduced, by the adoption of relatively simple measures during construction.

1. **Construction Runoff**

Infiltration BMPs should be constructed AFTER the site work is completed and stabilization measures have been implemented.

Infiltration facilities built prior to the completion of site construction activities often become choked with sediment, rendering them inoperable from the outset. Simply providing inlet protection or some other filtering mechanism during site construction may not adequately control the sediment. One large storm can overload protection devices and completely clog the infiltration facility.

To protect an infiltration facility **during** construction, provisions for sediment control should be included in the design. The following references provide technical guidance on sediment control designs:

, Virginia Erosion and Sediment Control Handbook (VESCH), DCR, 1992,
, Standards and Specifications for Infiltration Practices, Md. DNR, 1984, and
, Controlling Urban Runoff (MWCOG, 1987).

Experience with infiltration practices in other states has shown that stormwater management infiltration facilities must be protected until their contributing drainage areas have been adequately stabilized *(Maryland,1987).*

The definition of the term "adequately stabilized" when describing the contributing drainage area of an infiltration BMP is critical to the success of the facility. An approved erosion and sediment control plan will specify various devices for trapping sediment during construction, such as silt fences, diversions, sediment traps, etc. It will also specify measures and provide specifications for site stabilization. Following construction activities, the temporary sediment control measures should be removed at the direction of the erosion control inspector when, at a minimum, stabilization measures, such as seed and mulch, are in place. This does not mean, however, that stabilization has occurred. Often, it may take one or more full growing seasons before the pervious areas are fully stabilized, and the construction-related sediment load is controlled. **Therefore, provisions to bypass the stormwater around, or away from, the infiltration facility during the stabilization period should be implemented.**

2. Urban Runoff

A fully stabilized site will generate a particulate pollutant load resulting from natural erosion, lawn and garden debris such as leaves, grass clippings, mulch, roadway sand, etc. Various measures can be incorporated into the design to protect the facility and facilitate regular maintenance. The following discussion on pretreatment systems for infiltration facilities is adapted from the Northern Virginia BMP Handbook (NVPDC 1992) and Standards and Specifications for Infiltration Practices (Md. DNR, 1984).

Urban and ultra-urban development projects are usually limited to the use of infiltration trenches, which include ***dry wells***, ***porous pavement***, and ***roof downspout systems***. Runoff to any infiltration trench must be filtered to remove sediment prior to entering the structure.

Runoff to an infiltration trench is usually ***concentrated input***, which is conveyed by gutters, inlets, or pipes, and enters the facility at one or more points. Sediment control devices for *concentrated input* include in-line structures such as water quality inlets (Refer to **Minimum Standard 3.15, Manufactured BMP Systems**), sediment collection sumps or similar structures, provided there is an assured means of regular inspection and maintenance. Any pretreatment BMP which allows sediment- laden water to enter the infiltration facility upon failure of the pretreatment BMP should be avoided. Ideally, a clogged or failed pretreatment BMP should create a noticeable amount of overland flow bypassing the infiltration facility, which indicates that it is time to maintain the pretreatment decvice. Prompt maintenance of the pretreatment BMP will ensure that the infiltration facility remains intact.

The design of sediment control systems for concentrated input facilities invites innovation. Redundant controls or backup systems should be employed wherever there is an opportunity. One type of backup sediment control measure used for trenches with large diameter CMP pipe storage consists of lining the interior surface of the pipe with a geotextile fabric as shown in **Figure 3.10-3**. This continuous liner is held against the interior metal surface of the pipe by expandable rings. If routine monitoring reveals that the water is not being released from the pipe, the filter should be inspected and replaced as necessary. Note that the diameter of the pipe must be such that access for maintenance is possible.

Any sediment collection structure must be adequate to handle the expected flows. Therefore, filter systems should be designed with an additional capacity to account for eventual, partial clogging.

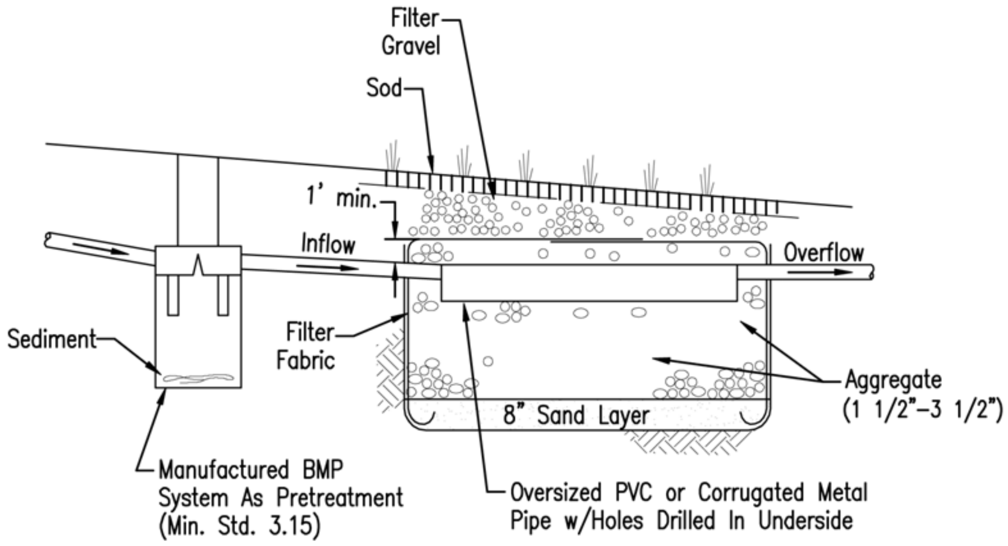
Runoff to an infiltration BMP may also be in the form of ***sheet flow***, entering the top of the storage reservoir over a wide area. **Figure 3.10-1b** portrays one such infiltration trench where overland sheet flow is directed across a gently sloping grassed filter strip to the surface of the infiltration trench. The grassed filter strip is the primary pretreatment control and must be at least **20 feet wide** and have a **5% slope or less** to be effective. The entry berm must be parallel to the contour to maintain uniform flow to the trench.

The choice of vegetative cover should be made with respect to its tolerance to water, growth rate, climatic preference, stabilization capacity, and maintenance considerations. Refer to the VESCH DCR, 1992, and any local ordinances for specific vegetative recommendations. It is essential that a complete cover of dense turf be established **BEFORE** stormwater flows are allowed to enter the facility.

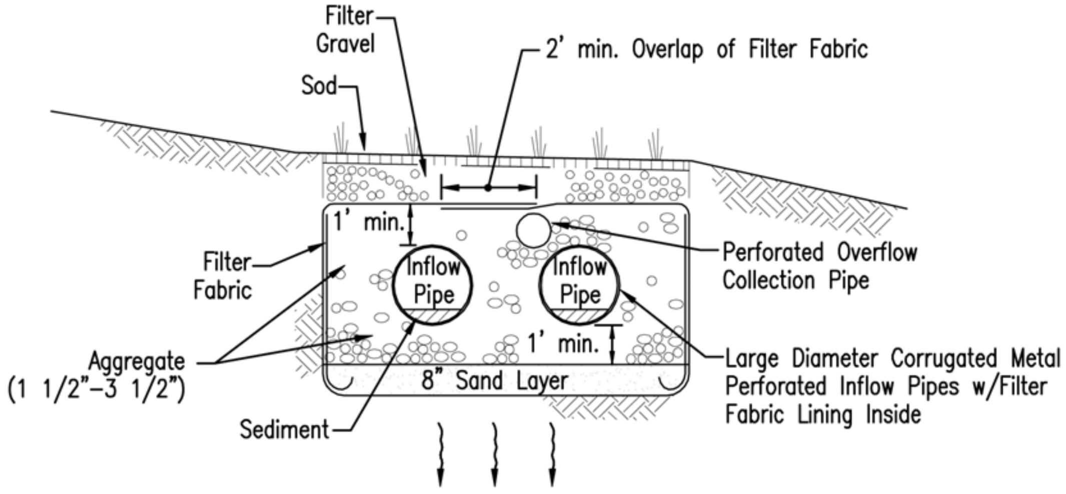
The trench itself is protected from sediment entry by a layer of geotextile filter fabric (called a *sediment barrier*). The sediment barrier is separate from the filter fabric which lines the trench sides so it can be replaced as part of routine maintenance. It is installed over the top of the crushed stone storage chamber and covered with one-half to one foot of 3/4-inch crushed stone. The edges of the filter fabric must be placed so that runoff cannot bypass the sediment barrier. All input water must flow over the grassed filter strip and enter the trench through the sediment barrier at the top.

Unlike the other trench types, porous pavement may be difficult to maintain because the pollutant load is carried by other means, such as vehicle traffic, rather than runoff. Porous pavement, therefore, requires a strict maintenance program to ensure that the design flow can pass through the pavement. Specific maintenance requirements, along with construction methods and specifications for porous pavement and various other infiltration BMPs, are provided later in this chapter.

FIGURE 3.10 - 3
Concentrated Input Pretreatment



PRETREATMENT – MANUFACTURED BMP SYSTEM



PRETREATMENT – OVERSIZED W/INTERIOR FILTER FABRIC

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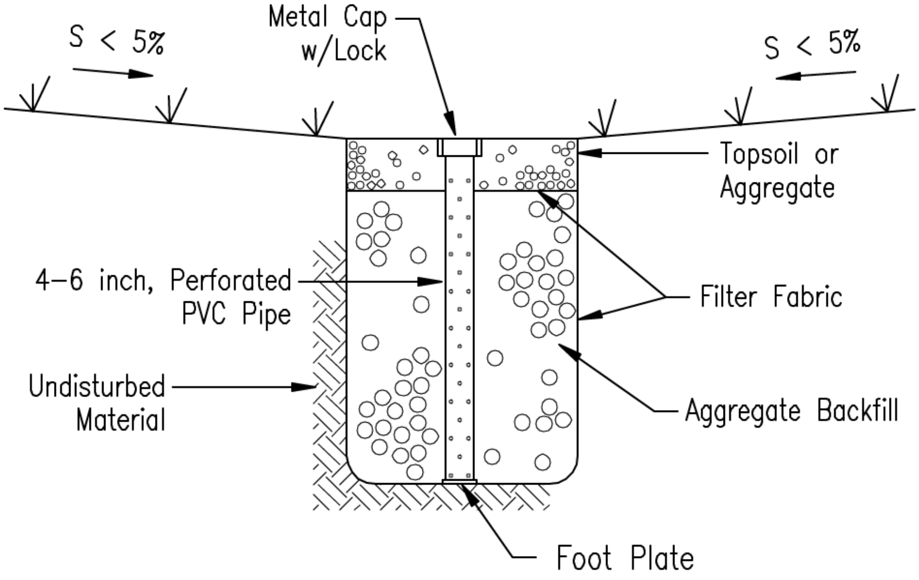
FIGURE 3.10 - 4
Observation Well



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Maintenance

The maintenance requirements for a selected infiltration practice must be considered during the planning and design of the facility. Surface facilities such as basins and swales can be visually inspected and easily maintained. The surface of an infiltration trench or dry well can also be visually inspected and maintained if they are constructed at grade. Since their subsurface storage areas cannot be inspected above ground, **observation wells must be required** (refer to **Figure 3.10-4**). Maintenance of the subsurface storage area, however, short of excavating the facility, is very difficult. Therefore, many landowners, developers and local program administrators have been discouraged from using infiltration facilities.

Recent studies indicated that slightly more than half of the surveyed infiltration facilities had failed within the first five years of operation (MWCOG, 1992; Md. DOE, 1987). Often, failure was due to poor subsurface investigations and/or sediment control. Since repair or rehabilitation of underground facilities (infiltration trenches) is limited, design criteria, subsurface exploration, and maintenance requirements should be strictly enforced. In addition, pretreatment of the stormwater runoff will likely extend the life of an infiltration facility by trapping sediments and debris before they enter, and by allowing for the removal of the accumulated material without excavating the structure. To reduce the potential for costly maintenance and/or system reconstruction, it is strongly recommended that the stone reservoir portion of infiltration trenches be located in a lawn area and as close to the ground surface as possible.

Infiltration trenches should not be located beneath paved surfaces, such as parking lots.

General Design

The purpose of this section is to provide recommendations and minimum criteria for the design of infiltration practices intended to comply with the runoff quality requirements of the Virginia Stormwater Management program.

The types of infiltration facilities which are recognized for stormwater management purposes are ***infiltration basins*** and ***infiltration trenches***. The design, construction, and maintenance criteria for infiltration trenches is also applied to the design of the storage volume for ***porous pavement*** and ***roof downspout systems*** (or *dry wells*).

The criteria presented below apply to the design of infiltration basins and trenches for ***water quality enhancement***. This means that the runoff volume to be treated is determined by the water quality volume and the desired pollutant removal efficiency.

Hydrology and Hydraulics

The procedures outlined in **Chapter 4, Hydrologic Methods**, should be used to determine the post-developed hydrology of the drainage area being served by the infiltration BMP. Provisions for large storm bypass must be provided, even when a stormwater BMP is being utilized for water quality enhancement only and not peak discharge control. Ideally, large storms should be diverted around infiltration facilities, or through the facility with a minimum of disruption and/or turbulence

Sizing Procedure

The storage volume required for infiltration facilities designed for water quality enhancement is determined by the water quality volume - ½ to 1 inch of runoff, determined by the desired pollutant removal efficiency (refer to **Table 3.10-1**).

A Darcy's Law approach is recommended for sizing water quality infiltration BMPs. This will assume that the drain time of the facility is controlled by one-dimensional flow through the bottom surface.

$$Q = f\,I\,SA$$

Equation 3.10-1
Darcy's Law

where: Q = rate of exfiltration into soil, cfs
f = infiltration rate of the soil in ft/hr
I = hydraulic gradient
SA = bottom surface area of facility in ft^2

1. **Infiltration Rate** –

Over the life of an infiltration facility, the rate of infiltration into the soil, f, may gradually decrease due to clogging of the surface layer of soil. The documented high failure rate of infiltration facilities (MWCOG) suggests that a safety factor be built into the design of the facility to allow for future clogging. Therefore, ***a safety factor of 2*** should be applied to the infiltration rate determined from the soil analysis. The design soil infiltration rate, f_d, therefore, is equal to one-half of the actual rate:

$$f_d = 0.5f$$

2. **Hydraulic Gradient –**

In areas with a shallow water table or impermeable layer, the hydraulic gradient may have an impact on the allowable design depth. The hydraulic gradient is given by the equation:

$$I = \frac{h + L}{L}$$

Equation 3.10-2
Hydraulic Gradient

where: I = hydraulic gradient

h = height of the water column over the infiltrating surface, ft.
L = distance from the top surface of the BMP to the water table, bedrock, impermeable layer, or other soil layer of a different infiltration rate, ft.

The hydraulic gradient will be asummed to be equal to one in all infiltration designs since the gradient approaches unity as the facility drains. Therefore,

$$I=1$$

3. Maximum Ponding or Storage Time, T_{max} –

A water quality infiltration facility should be designed with a maximum drain time, T_{max}, of 48 hours for the total volume.

The maximum drain time, along with the minimum design soil infiltration rate, f_d, as verified through a subsurface investigation and analysis, will dictate the maximum allowable design depth, d_{max}, of the structure. The maximum depth for an infiltration basin and trench is covered in the following minimum standards.

MINIMUM STANDARD 3.10A

INFILTRATION BASIN

Definition

An infiltration basin is a vegetated, open impoundment where incoming stormwater runoff is stored until it gradually infiltrates into the soil strata.

Purpose

Infiltration basins are used primarily for water quality enhancement. However, flooding and channel erosion control may also be achieved within an infiltration basin by utilizing a multi-stage riser and barrel spillway to provide controlled release of the required design storms above the water quality (infiltration) volume (refer to **Figure 3.10-1**).

Conditions Where Practice Applies

Infiltration basins may be used where the subsoil is sufficiently permeable to provide a reasonable infiltration rate and where the water table is low enough to prevent pollution of groundwater.

<u>Drainage Area</u>

Drainage areas served by infiltration basins should be limited to less than 50 acres. Drainage areas which are greater than 50 acres typically generate such large volumes of runoff that other detention or retention BMPs are more practical and cost-effective.

<u>Development Conditions</u>

Infiltration basins are generally suitable BMPs in low- to medium-density residential and commercial developments (38% to 66% impervious cover).

Planning Considerations

Appropriate soil conditions and protection of the groundwater are among the important considerations when planning an infiltration basin. Refer to the **Planning Considerations** for **General Infiltration Practices** previously discussed in this standard.

An infiltration basin has relatively large surface area requirements, when compared with an infiltration trench or dry well, and ranges from 3 to 12 feet in depth. The seasonal high groundwater table or bedrock should be located at least 2 to 4 feet below the bottom of the basin. Infiltration facilities are not recommended for areas where karst topography is present (in Virginia, west of the Blue Ridge Mountains) due to the possibility of causing subsurface collapse and sink hole formation.

Maintenance

Like all stormwater BMPs, access to an infiltration basin should be considered in the planning stage. Access (as well as maneuvering room) should be provided to at least one side of the facility and the control structure or spillway. In addition, identifying a location and designing for on-site sediment disposal will greatly reduce long-term maintenance costs.

Design Criteria

The purpose of this section is to provide recommendations and minimum criteria for the design of infiltration basins intended to comply with the runoff quality requirements of the Virginia Stormwater Management program.

General

The design of infiltration basins should be according to the following Minimum Standards where applicable: **3.01, Earthen Embankment**; **3.02, Principal Spillway**; **3.03, Vegetated Emergency Spillway**; **3.04, Sediment Forebay**; **3.05, Landscaping**, and **3.10, General Infiltration Practices**, along with additional criteria set forth below. The designer is not only responsible for selecting the appropriate components for his or her particular design but also for ensuring their long-term operation by specifying appropriate structural materials.

The design of the overflow vegetated spillway must consider the frequency of flow. The spillway may require an armored bottom if it is to function during every storm which exceeds the water quality volume (refer to **Minimum Standard 3.03**).

Hydrology and Hydraulics

Chapter 4, **Hydrologic Methods** should be used to develop the pre- and post-developed hydrology for a basin's contributing watershed. An infiltration basin designed for water quality enhancement still must provide an overflow or spillway for the bypass of large storms. **Chapter 5**, **Engineering Calculations** provides the procedures for the design of the riser and barrel system and the emergency spillway design procedures.

Soils Investigation

A minimum of one soil boring log should be required for each 5,000 square feet of infiltration basin area (plan view area) and under no circumstances should there be less than three soil boring logs per basin (Washington State DOE, 1992). Refer also to the **Planning Considerations** and **Design Criteria** of **General Infiltration Practices**, discussed at the beginning of this standard.

Topographic Conditions

Infiltration basins should be a minimum of 50 feet from any slope greater than 15%. If unavoidable, a geotechnical report should address the potential impact of infiltration on or near the steep slope. Developments on sloping sites often require extensive cut and fill operations. **The use of infiltration basins on fill sites is not permitted**. Also, infiltration basins should be a minimum of 100 feet up-slope and 20 feet down-slope from any buildings.

Design Infiltration Rate

The design infiltration rate, f_d, should be set to equal one-half the infiltration rate, f, determined from the soil analysis. Therefore:

$$f_d = 0.5\,f$$

Maximum Ponding Time and Depth

All infiltration basins should be designed to completely drain stored runoff within 2 days following the occurrence of a storm event. Thus, an allowable maximum ponding time, T_{max} , of 48 hours should be used.The maximum ponding depth for an infiltration **basin** is:

$$d_{max} = f_d T_{max}$$

Equation 3.10-3
Maximum Ponding Depth for Infiltration Basin

where: d_{max} = maximum depth of the facility, in ft.
f_d = design infiltration rate of the basin area soils, in ft/hr ($f_d = \frac{1}{2} f$)
T_{max} = maximum allowable drain time = 48 hrs.

The ponding depth should not be so great as to contribute to the compaction of the soil surface. Depending on the specific soil characteristics, a maximum ponding depth of 2 feet is generally recommended (MWCOG, 1992).

The minimum surface area of the facility bottom is:

$$SA_{min} = \frac{Vol_{wq}}{f_d T_{max}}$$

Equation 3.10-4
Minimum Bottom Surface Area for infiltration Basin

where: SA_{min} = minimum basin bottom surface area, in ft^2;
Vol_{wq} = water quality volume requirements, in ft^3;
f_d = design infiltration rate of the basin area soils, in ft/hr;
T_{max} = maximum allowable drain time, in hours

Runoff Pretreatment

Infiltration basins should always be preceded by a pretreatment facility. Grease, oil, floatable organic materials, and settleable solids should be removed from the runoff before it enters the infiltration basin. Vegetated filters, sediment traps and/or forebays, water quality inlets (refer to **Minimum Standard 3.15, Manufactured BMP Systems**) are just a few of the available pretreatment strategies. Refer to the discussion on **Sediment Control** in the **General Infiltration Practices** portion of this section.

At a minimum, the layout and design of the basin should include a sediment forebay or pretreatment cell, as shown in **Figure 3.10-1**, to enhance and prolong the infiltration capacity. Any pretreatment facility should be included in the design of the basin and should include maintenance and inspection requirements. It is recommended that a grass strip or other vegetated buffer at least 20 feet wide be maintained around the basin to filter surface runoff.

Principal and Emergency Spillways

A diversion structure upstream of an ***off-line*** basin will regulate the rate of flow into the basin, but not the volume. Therefore, infiltration basins should have a spillway to convey flows from storm events which are larger than the design capacity. The primary outlet should be located above the required infiltration volume. Additionally, a riser and barrel system is advantageous for future conversion to an extended-detention or retention facility if the infiltration capacity of the soil becomes impaired. All design elements of a principal spillway should be per **Minimum Standard 3.02, Principal Spillways**.

An emergency spillway is recommended for all impounding structures, including infiltration basins. If a vegetated spillway is to be used as the primary outlet above the water quality volume, care should be taken to design for the increased frequency of use. This is especially critical between maintenance operations when the infiltration capacity is decreased due to sediment loads. If a spillway is to be used for all storms which generate more runoff than the water quality volume, then a nonerodible surface should be provided. All design elements of a *vegetated* emergency spillway should be per **Minimum Standard 3.03, Vegetated Emergency Spillways**.

Stabilization

As with all stormwater structures, all disturbed areas associated with the construction of the facility, including spoil and borrow areas, should be stabilized immediately according to the VESCH 1992 edition. The basin floor area, emergency spillway, and any vegetative buffer around the facility are critical areas and should be addressed with a specific stabilization measure.

The choice of vegetative cover should be made with respect to its tolerance to water, growth rate, climatic preference, stabilization capacity, and maintenance requirtements. Refer to the VESCH 1992 edition and any local ordinances for specific vegetative recommendations. It is essential that a complete cover of dense turf be established **BEFORE** stormwater flows are allowed to enter the facility.

Fencing

Fencing may be provided where deemed necessary by the developer, land owner, or locality for the purposes of public safety or protection of vegetation.

Construction Specifications

In general, widely accepted construction standards and specifications, such as those developed by the USDA Soil Conservation Service or the U.S. Army Corps of Engineers, should be followed where applicable. Further guidance can be found in the Soil Conservation Service's Engineering Field Manual. Specifications for the work should conform to the methods and procedures indicated for installing earthwork, concrete, reinforcing steel, pipe, water gates, metal work, woodwork and masonry as they apply to the site and the purpose of the structure. The specifications should also satisfy all requirements of the local government.

The construction of infiltration basins should also be in accordance with the following Minimum Standards and Specifications where applicable: **3.01, Earthen Embankment**; **3.02, Principal Spillway**; **3.03, Vegetated Emergency Spillway**; **3.04, Sediment Forebays**; **3.05, Landscaping**; along with the criteria set forth below. These specifications have been adapted from Standards & Specifications for Infiltration Practices (Md. DNR, 1984 and Washington State DOE, 1992).

Sequence of Construction

The sequence of various phases of basin construction should be coordinated with the overall project construction schedule. Rough excavation of the basin may be scheduled with the rough grading phase of the project to permit use of the material as fill in earthwork areas. Otherwise, **infiltration measures should not be constructed or placed into service until the entire contributing drainage area has been stabilized**. Runoff from untreated, recently constructed areas within the drainage area may load the newly formed basin with a large volume of fine sediment. This could seriously impair the natural infiltration ability of the basin floor.

The specifications for construction of a basin should state the following: 1) *the earliest point at which storm drainage may be directed to the basin*, and 2) *the means by which this delay in basin use is to be accomplished*. Due to the wide variety of conditions encountered among projects, each project should be evaluated separately to postpone basin use for as long as possible.

Excavation

Initially, the basin floor should be excavated to within one foot of its final elevation. Excavation to the finished grade should be delayed until all disturbed areas in the watershed have been stabilized or protected. The final phase of excavation should remove all accumulated sediment. Relatively light, tracked-equipment is recommended for this operation to avoid compaction of the basin floor. After the final grading is completed, the basin floor should be deeply tilled by means of rotary tillers or disc harrows to provide a well-aerated, highly porous surface texture.

Lining Material

Establishing dense vegetation on the basin side slopes and floor is recommended. A dense vegetative cover will not only prevent erosion and sloughing, but will also provide a natural means to maintain relatively high infiltration rates. Inflow points to the basin should also be protected with erosion controls (e.g., riprap, flow spreaders, energy dissipators, etc.), as well as a sediment forebay.

Selection of suitable vegetative materials and application of required fertilizer and mulch should be per the VESCH 1992 edition.

Maintenance / Inspection Guidelines

The following maintenance and inspection guidelines are not intended to be all-inclusive. Specific facilities may require other measures not discussed here.

Inspection Schedule

When infiltration basins are first made functional they should be inspected monthly and after any large storm event. Thereafter, once the basin is functioning satisfactorily and without potential sediment problems, inspections may be made semi-annually and after any large storm events. All inspections should include investigation for potential sources of contamination.

Sediment Control

The basin should be designed to allow for maintenance. Access should be provided for vehicles to easily maintain the forebay (pre-settling basin) without disturbing vegetation or sediment any more than what is absolutely necessary.

Grass bottoms in infiltration basins seldom need replacement since grass serves as a good filter material. If silty water is allowed to trickle through the turf, most of the suspended material is strained out within a few yards of surface travel. Well-established turf on a basin floor will grow up through sediment deposits forming a porous turf and preventing the formation of an impenetrable layer. Grass planted on basin side slopes should also prevent erosion.

Vegetation Maintenance

Maintenance of the vegetation on the basin floor and side slopes is necessary to promote a dense turf with extensive root growth, which subsequently enhances infiltration, prevents erosion and sedimentation, and deters invasive weed growth. Bare spots should be immediately stabilized and revegetated.

The use of low-growing, stoloniferous grasses will permit long intervals between mowings. Mowing twice a year is generally satisfactory. Fertilizers should be applied only as necessary and in limited amounts to avoid contributing to pollution problems, including groundwater pollution, for which the infiltration basin helps mitigate. Consult the VESCH, 1992 edition for appropriate fertilizer types and application rates.

Design Procedures

The following design procedure represents a generic list of the steps typically required for the design of an infiltration basin.

1. Determine if the anticipated development conditions and drainage area are appropriate for an infiltration basin application.

2. Determine if the soils (permeability, bedrock, water table, Karst, embankment foundation, etc.) and topographic conditions (slopes, building foundations, etc.) are appropriate for an infiltration basin application.

3. Locate the infiltration basin on the site within topographic constraints.

4. Determine the drainage area to the infiltration basin and calculate the required water quality volume.

5. Evaluate the hydrology of the contributing drainage area to determine peak rates of runoff.

6. Design the infiltration basin:
    - Design infiltration rate, $f_d = 0.5 f$.
    - Max. Storage time $T_{max} = 48$ hours
    - Max. Storage depth, d_{max}
    - Runoff pretreatment - concentrated input, sheet flow input, sediment forebay
    - Vegetated buffer around basin to filter surface runoff
    - Vegetated emergency spillway and/or riser and barrel design
    - Earthen Embankment design

7. Provide material specifications.

8. Provide sequence of construction.

9. Provide maintenance and inspection requirements.

MINIMUM STANDARD 3.10B

INFILTRATION TRENCH

Definition

An infiltration trench is a shallow, excavated trench backfilled with a coarse stone aggregate to create an underground reservoir. Stormwater runoff diverted into the trench gradually infiltrates into the surrounding soils from the bottom and sides of the trench. The trench can be either an open surface trench or an underground facility.

Purpose

Infiltration trenches are used primarily as water quality BMPs. Trenches are generally 2 to 10 feet deep and are backfilled with a coarse stone aggregate, allowing for temporary storage of storm runoff in the voids between the aggregate material. Stored runoff gradually infiltrates into the surrounding soil. The surface of the trench can be covered with grating and/or consist of stone, gabion, sand, or a grassed area with a surface inlet. Utilizing underground pipes within the trench can increase the temporary storage capacity of the trench and can sometimes provide enough storage for flooding and/or stream channel erosion control (see **Figure 3.10-3**).

Conditions Where Practice Applies

An infiltration trench may be used where the subsoil is sufficiently permeable to provide a reasonable infiltration rate and where the water table is low enough to prevent pollution of groundwater.
Infiltration facilities are not recommended for areas where karst topography is present (in Virginia, west of the Blue Ridge Mountains) due to the possibility of causing subsurface collapse and sink hole formation.

Drainage Area

Infiltration trenches are not practical for large drainage areas. Generally, the drainage area for infiltration trenches should be limited to 5 acres. Multiple trenches may be considered to control the runoff from a large site, but this also increases the associated maintenance responsibilities.

Development Conditions

Infiltration trenches are generally suited for low- to medium-density residential and commercial developments. They can be installed in multi-use areas, such as along parking lot perimeters, or in small areas that cannot readily support retention basins or similar structures. Infiltration trenches can be used in residential areas, commercial areas, parking lots and open space areas. Unlike most BMPs, trenches can easily fit into the margin, perimeter, or other unused areas of developed sites, making them particularly suitable for retrofitting in existing developments or in conjunction with other BMPs. A trench may also be installed under a swale to increase the storage of the related infiltration system. In all cases, pretreatment of the stormwater runoff to remove course sediment and particulate pollutants prior to entering the infiltration trench should be provided.

Planning Considerations

Appropriate soil conditions and protection of groundwater are two important considerations when planning for an infiltration trench. For further discussion, refer to the **Planning Considerations** previously discussed in **General Infiltration Practices, Minimum Standard 3.10**.

Design Criteria

The purpose of this section is to provide recommendations and minimum criteria for the design of infiltration trenches intended to comply with the runoff quality requirements of the Virginia Stormwater Management program.

General

Infiltration trenches are assumed to have rectangular cross-sections. Thus, the infiltration surface area (trench bottom) can be readily calculated from the trench geometry. The storage volume of the trench must be calculated using the void ratio of the backfill material that will be placed in it.

The same general criteria presented for the design of infiltration basins apply to trenches; the following information is provided for additional guidance.

Soils Investigation

A minimum of one soil boring log should be required for every 50 feet of trench length. A minimum of two soil boring logs should be required for each proposed trench location (Washington State DOE, 1992).

Topographic Conditions

Infiltration trenches should be located 20 feet down-slope and 100 feet up-slope from building foundations. An analysis should be completed to identify any possible adverse effects of seepage zones if there are nearby building foundations, basements, roads, parking lots or sloping sites. Developments on sloping sites often require the use of extensive cut and fill operations. **The use of infiltration trenches on fill sites is not permitted**.

Design Infiltration Rate

The design infiltration rate, f_d, should be set to equal one-half the infiltration rate obtained from the soil analysis. Therefore,

$$f_d = 0.5\,f$$

Maximum Storage Time and Trench Depth

All infiltration trenches should be designed to empty within 2 days following the occurrence of a storm event. Thus, a maximum allowable storage time, T_{max}, of 48 hours should be used.

The maximum depth for an infiltration **trench** may be defined as:

$$d_{max} = \frac{f_d T_{max}}{V_r}$$

Equation 3.10-5
Maximum Depth for Infiltration Trench

where:
d_{max} = maximum allowable depth of the facility, in ft;
f_d = design infiltration rate of the trench area soils, in ft/hr ($f_d = 0.5f$);
T_{max} = maximum allowable drain time = 48 hrs.;
V_r = void ratio of the stone reservoir expressed in terms of the percentage of porosity divided by 100 (0.4 typ.).

Refer to the Virginia Department of Transportation's Road and Bridge Specifications, latest edition, for information and specifications for coarse aggregates. A void ratio of 0.40 is assumed for stone reservoirs using 1.5 to 3.5 inch stone - VDOT No. 1 Coarse-graded Aggregate.

The minimum surface area of the facility bottom may be defined as:

$$SA_{min} = \frac{Vol_{wq}}{f_d T_{max}}$$

Equation 3.10-6
Infiltration Trench Minimum Bottom Surface Area

where: SA_{min} = minimum trench bottom surface area, in ft^2;
Vol_{wq} = water quality volume requirements, in ft^3;
f_d = design infiltration rate of the trench area soils, in ft/hr ($f_d = 0.5f$);
T_{max} = maximum allowable drain time = 48 hrs.

Runoff Pretreatment

Infiltration trenches should always be preceded by a pretreatment facility. Grease, oil, floatable organic materials, and settleable solids should be removed from the runoff before it enters the trench. Vegetated filters, sediment traps or forbays, water quality inlets (refer to **Minimum Standard 3.15, Manufactured BMP Systems**) are just a few of the available pretreatment strategies. To reduce both the frequency of turbulent flow-through and the associated scour and/or resuspension of residual material, infiltration trenches and associated pretreatment facilities should be installed off-line (MWCOG, 1992). Additional pretreatment arrangements are illustrated in **Figure 3.10-3**. Refer to the discussion on **Sediment Control** in **General Infiltration Practices**, **Minimum Standard - 3.10**.

A grass strip or other type of vegetated buffer at least 20 feet wide should be maintained around trenches that accept surface runoff as sheet flow. The slope of the filter strip should be approximately 1% along its entire length and 0% across its width. A recent study by MWCOG (Galli, 1992) concluded that for areas receiving high suspended solid loads, a minimum filter length of 50 feet is desirable.

All trenches with surface inlets should be engineered to capture sediment from the runoff before it enters the stone reservoir. Any pretreatment facility design should be included in the design of the trench, complete with maintenance and inspection requirements.

Backfill Material

Backfill material for the infiltration trench should be clean aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches (i.e., VDOT No. 1 Open-graded Coarse Aggregate or equivalent). The aggregate should contain few aggregates smaller than the selected size. Void spaces for VDOT No. 1 aggregate is assumed to be 40 percent.

An 8 inch deep bottom sand layer (VDOT Fine Aggregate, Grading A or B) is required for all trenches to promote better drainage and reduce the risk of soil compaction when the trench is backfilled with stone (MWCOG, 1992).

Filter Fabric

The aggregate fill material should be surrounded with an engineering filter fabric as shown in **Figure 3.10-5**. For an aggregate surface trench, filter fabric should surround all of the aggregate fill material except the top one foot. A separate piece of fabric should be used for the top layer to act as a failure plane. This top piece can then be removed and replaced upon clogging. Note, however, that filter fabric should **not** be placed on the trench bottom. Refer to the VESCH 1992 edition, for filter fabric specifications.

Overflow Channel

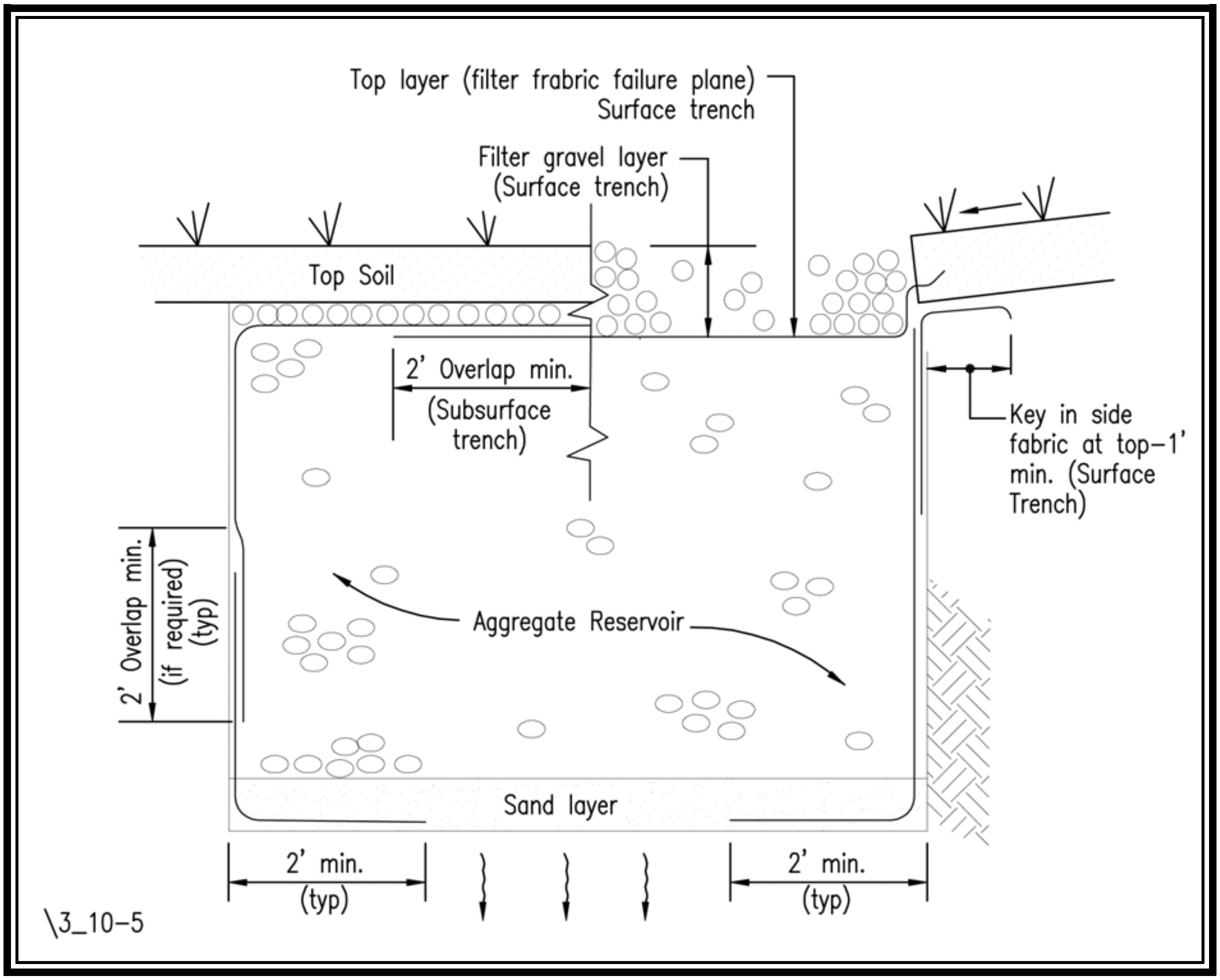
Usually, because of the small drainage areas controlled by an infiltration trench, an emergency spillway is not necessary. However, the overland flow path taken by the surface runoff, when the capacity of the trench is exceeded, should always be evaluated. A nonerosive overflow channel leading to a stabilized watercourse should be provided, as necessary, to insure that uncontrolled, erosive, concentrated flow does not develop.

Observation Well

An observation well should be installed for every 50 feet of infiltration trench length. The observation well will show how quickly the trench dewaters following a storm, as well as providing a means of determining when the filter fabric is clogged and maintenance is needed (refer to **Figure 3.10-4**).

The observation well should consist of perforated PVC pipe, 4 to 6 inches in diameter. It should be installed in the center of the structure, flush with the ground elevation of the trench. Putting the observation well in a non-parking or traffic area to simplify inspections is best. The top of the well should be capped to discourage vandalism and tampering.

FIGURE 3.10 - 5
Filter Fabric Placement



Construction Specifications

Overall, widely accepted construction standards and specifications, such as those developed by the USDA Soil Conservation Service or the U.S. Army Corps of Engineers, should be followed where applicable. Further guidance can be found in the Soil Conservation Service's Engineering Field Manual. Specifications for the work should conform to the methods and procedures indicated for installing earthwork, concrete, reinforcing steel, pipe, water gates, metal work, woodwork and masonry, as they apply to the site and the purpose of the structure. The specifications should also satisfy any requirements of the local government.

Construction of an infiltration trench should also be in conformance with the following:

Sequence of Construction

An infiltration trench should not be constructed or placed into service until all of the contributing drainage area has been stabilized. Runoff from untreated, recently constructed areas within the drainage area may load the newly formed trench and/or pretreatment facility with a large volume of fine sediment.

The specifications for the construction of an infiltration trench should state the following: 1) *the earliest point at which storm drainage may be directed to the trench*, and 2) *the means by which this delay in use is to be accomplished*. Due to the wide variety of conditions encountered among development projects, each project should be evaluated separately to postpone trench use for as long as possible.

Trench Preparation

Trench excavation should be limited to the specific trench dimensions. Excavated materials should be placed away from the trench sides to avoid impacting the trench wall stability.

The trench should be excavated with a backhoe or similar device that allows the equipment to stand away from the trench bottom. This bottom surface should be scarified with the excavator bucket teeth on the final pass to eliminate any smearing or shearing of the soil surface. Similarly, the sand filter material should be placed on the trench bottom so that it does not compact or smear the soil surface. The sand must be deposited ahead of the loader so the equipment is always supported by a minimum of 8 inches of sand.

Large tree roots must be trimmed flush with the trench sides to prevent the fabric from puncturing or tearing during subsequent installation procedures. No voids between the filter fabric and the excavation walls should be present. If boulders or similar obstacles are removed from the excavated walls, natural soils should be placed in these voids before the filter fabric is installed. The side walls of the trench should be roughened where sheared and sealed by heavy equipment.

Vertically excavated walls may be difficult to maintain in areas where the soil moisture is high or where soft cohesive or cohesionless soils predominate. These conditions may require that the side slopes be laid back to maintain stability; trapezoidal rather than rectangular cross sections may result.

Fabric Laydown

The roll of filter fabric should be cut to the proper width before installation. The width should allow for perimeter irregularities plus a minimum 12-inch overlap at the top. When a fabric overlap is required elsewhere, the upstream section should overlap the downstream section by a minimum of 2 feet to ensure that the fabric conforms to the excavation surface during aggregate placement. Note that filter fabric should **not** be placed on the trench bottom.

Stone Aggregate Placement Compaction

The crushed stone aggregate should be placed in the trench in loose lifts of about 12 inches using a backhoe or front-end loader with a drop height near the bottom of the trench, and should be lightly compacted with plate compactors. Aggregate should not be dumped into the trench by a truck.

Backfill material for the infiltration trench should be clean, washed aggregate *1.5* to *3.5* inches in diameter (VDOT No. 1 Open-graded Coarse Aggregate or equivalent). The aggregate should contain few aggregates smaller than the selected size.

The 8 inch deep bottom sand layer should consist of VDOT Fine Aggregate, Grading A or B.

Overlapping and Covering

Following the stone aggregate placement, the filter fabric should be folded over the stone aggregate to form a 12-inch minimum longitudinal overlap. The desired fill soil or stone aggregate should be placed over the lap at sufficient intervals to maintain the lap during subsequent backfilling.

Potential Contamination

Clean aggregate **should not** be mixed with natural or fill soils. All contaminated aggregate should be removed and replaced with clean aggregate.

Traffic Control

To prevent or reduce compaction of the soil, heavy equipment and traffic should not travel over the infiltration trench.

Observation Well

Observation wells should be provided as specified in the design criteria. The depth of the well at the time of installation should be clearly marked on the well cap.

Maintenance / Inspection Guidelines

The following maintenance and inspection guidelines are not intended to be all-inclusive. Specific facilities may require other measures not discussed here.

Inspection Schedule

The observation well and pretreatment facility should be monitored quarterly and after every large storm event. It is recommended that a log book be maintained showing the depth of water in the well at each observation in order to determine the rate at which the facility dewaters after runoff producing storm events. Once the performance characteristics of the structure have been verified, the monitoring schedule can be reduced to an annual basis, unless the performance data suggest that a more frequent schedule is required.

Sediment Control

Sediment buildup in the top foot of stone aggregate or the surface inlet should be monitored on the same schedule as the observation well. A monitoring well in the top foot of stone aggregate should be provided when the trench has a stone surface. Sediment deposited should not be allowed to build up to the point where it will reduce the infiltration rate into the trench.

It is recognized that infiltration facilities are subject to clogging. Once a trench facility has clogged, very little can be done to correct it, short of excavating the facility. Maintenance efforts, therefore, should focus on the measures used for pretreatment of runoff, in addition to the facility itself.

Vegetation Maintenance

Any vegetated buffers associated with an infiltration trench should be inspected regularly and maintained as needed. Regular maintenance of the buffer is necessary to promote dense turf with extensive root growth, which subsequently enhances runoff filtering, prevents erosion and sedimentation, and deters invasive weed growth. Bare spots should be immediately stabilized and revegetated. Fertilizers should be applied only as necessary and in limited amounts to avoid contributing to pollution problems which the infiltration basin helps to mitigate. Consult the VESCH 1992 edition for appropriate fertilizer types and application rates.

Design Procedures

The following design procedure represents a generic list of the steps typically required for the design of an infiltration trench.

1. Determine if the anticipated development conditions and drainage area are appropriate for an infiltration trench application.

2. Determine if the soils (permeability, bedrock, water table, Karst, etc.) and topographic conditions (slopes, building foundations, etc.) are appropriate for an infiltration trench application.

3. Locate the infiltration trench on the site within topographic constraints.

4. Determine the drainage area for each infiltration trench and calculate the required water quality volume.

5. Evaluate the hydrology of the contributing drainage area to determine peak rates of runoff.

6. Design the infiltration trench:
    - design infiltration rate, $f_d = 0.5 f$
    - max. storage time $T_{max} = 48$ hours
    - max. storage depth, d_{max}
    - stone backfill of clean aggregate (1.5" to 3.5") VDOT No. 1 Open-Graded Course Aggregate
    - sand layer on trench bottom (8 inches)
    - runoff pretreatment - concentrated input, sheet flow input
    - vegetated buffer around trench to filter surface runoff
    - filter fabric on trench sides and top (not on trench bottom) keyed into trench
    - overflow channel or large storm bypass
    - observation well

7. Provide material specifications.

8. Provide sequence of construction.

9. Provide maintenance and inspection requirements.

MINIMUM STANDARD 3.10C

ROOF DOWNSPOUT SYSTEM

Definition

A roof downspout system is an infiltration trench practice intended only for infiltrating rooftop runoff transported to the trench via roof downspout drains.

Purpose

The purpose of a roof downspout system is to provide water quality enhancement of rooftop runoff via infiltration of the water quality volume into the surrounding soils. This facility is not designed to infiltrate other surface water that could transport sediment or pollutants, such as from paved areas.

Conditions Where Practice Applies

Roof downspout systems may be used in any situation where disposing of rooftop runoff without direct connections to existing drainage systems or BMPs is acceptable and advantageous. Because of their small size, they are well suited for retrofitting in areas where runoff control of existing or new rooftop areas associated with building additions becomes necessary. As part of a low impact development strategy, roof downspout systems effectively disconnect the rooftop imperviousness from the drainage system which helps reduce the stormwater impact of the development. Use of roof downspout systems (or infiltration trenches in general) in residential areas should be used with caution due to concern for the potential lack of inspections and maintenance, and ultimate failure and abandonment of the facility.

Planning Considerations

The planning considerations for roof downspout systems are the same as those for infiltration trenches (**Minimum Standard 3.10B**). The drainage area is limited to the rooftop areas of residential and/or commercial structures.

Design Criteria

This section provides recommendations and minimum criteria for the design of roof downspout systems intended to comply with the runoff quality requirements of the Virginia Stormwater Management program.

The design criteria for roof downspout systems are the same as those for infiltration trenches with the following exceptions and/or additions:

Distance from Structures

Roof downspout systems should be a minimum of 10 feet down-slope from any structure or property line, and 30 feet from any septic tank or drain field.

Runoff Pre-Treatment

Gutters should be fitted with mesh screens to prevent leaf litter and other debris from entering the system in areas where there is tree cover. The expected growth of newly planted trees should be considered.

A pretreatment settling basin as shown in **Figure 3.10-6** should be provided on all roof downspout systems.

Overflow

An overflow outlet should be provided on the downspout at the surface elevation to allow flow to bypass the infiltration facility when it is full or clogged. (See **Figure 3.10-6**.)

Adequate surface drainage away from the structure should be provided according to appropriate building codes.

Construction Specifications

The construction specifications for roof downspout systems are the same as those for infiltration trenches.

Maintenance and Inspection Guidelines

Maintenance procedures are identical for those of an infiltration trench. Since these facilities are installed on individual buildings and other structures, provisions need to be made for their maintenance, especially when they are installed on single family dwellings. When flow is observed to be bypassing the facility, the system has clogged and should be evaluated for rehabilitation.

Design Procedures

The following design procedure represents a generic list of the steps typically required for the design of a roof downspout system.

1. Determine if the anticipated development conditions and rooftop areas are appropriate for a roof downspout system.

2. Determine if the soils (permeability, bedrock, water table, Karst, etc.) and topographic conditions (slopes, building foundations, etc.) are appropriate for a roof downspout system.

3. Locate the roof downspout system on the site within site topographic constraints.

4. Determine the roof area for each roof downspout system and calculate the required water quality volume.

5. Design the roof downspout system:
   - design infiltration rate, $f_d = 0.5 f$
   - max. Storage time $T_{max} = 48$ hours
   - max. Storage depth, d_{max}
   - stone backfill of clean aggregate (*1.5*" to *3.5*" diameter) - VDOT No. 1 Open-graded Course Aggregate
   - sand layer on trench bottom (*8* inches
   - runoff pretreatment - concentrated input: gutter screens, settling basin
   - filter fabric on trench sides and top (not on trench bottom) keyed into trench
   - overflow channel or large storm bypass
   - observation well

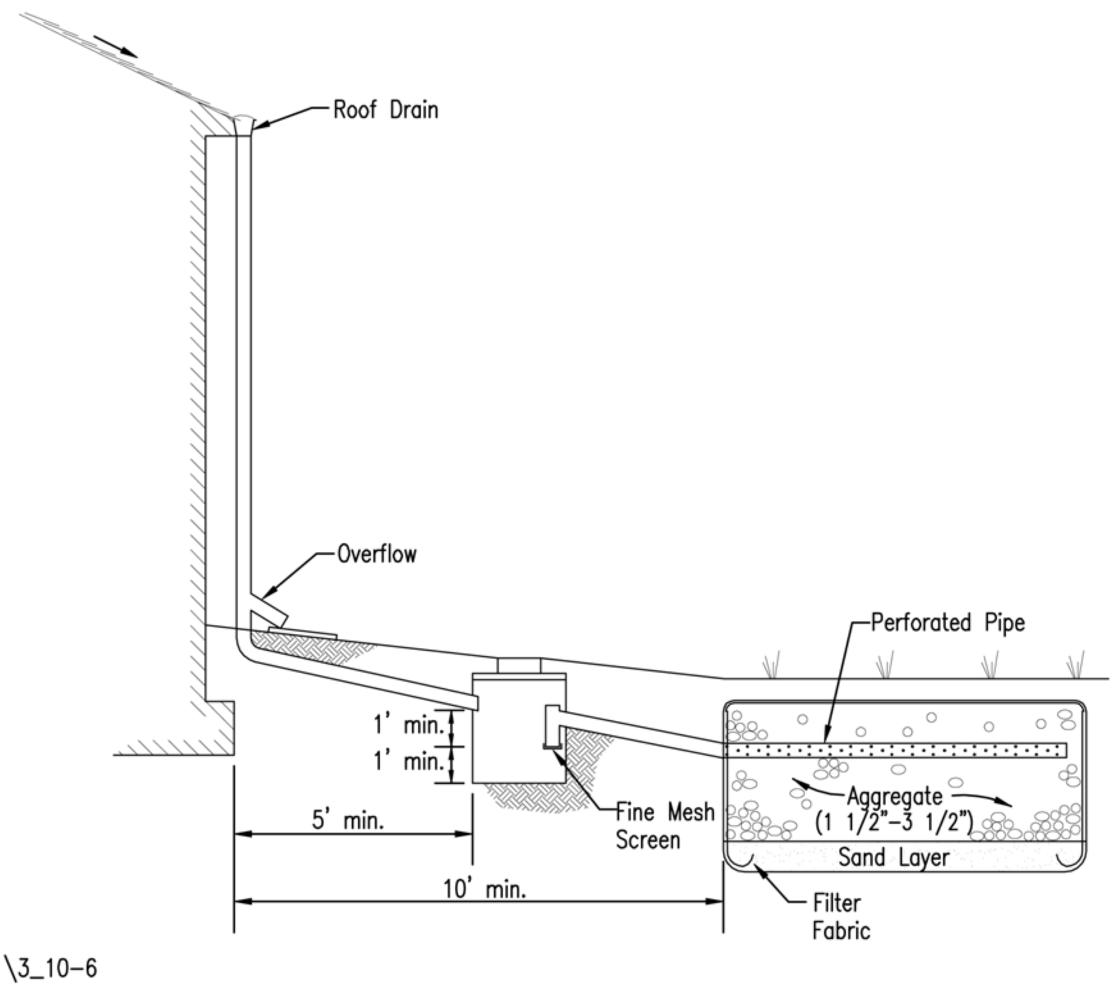
6. Provide material specifications.

7. Provide sequence of construction.

8. Provide maintenance and inspection requirements.

FIGURE 3.10 - 6

Roof Downspout System with a Pretreatment Sump Basin



MINIMUM STANDARD 3.10D

POROUS PAVEMENT

Definition

Porous pavement is a pervious pavement placed over a stone reservoir that is installed above a permeable soil.

The two pavements discussed in this section are ***porous asphalt pavement*** and ***porous concrete pavement***. *Porous asphalt pavement* is an open-graded coarse aggregate, bound together by asphalt cement into a coherent mass, with sufficient interconnected voids to provide a high rate of permeability to water. A typical porous asphalt pavement cross-section is presented in **Figure 3.10-11**. *Pourous concrete pavement* consists of specially formulated mixtures of Portland Cement, uniform, open-graded coarse aggregate and potable water.

Purpose

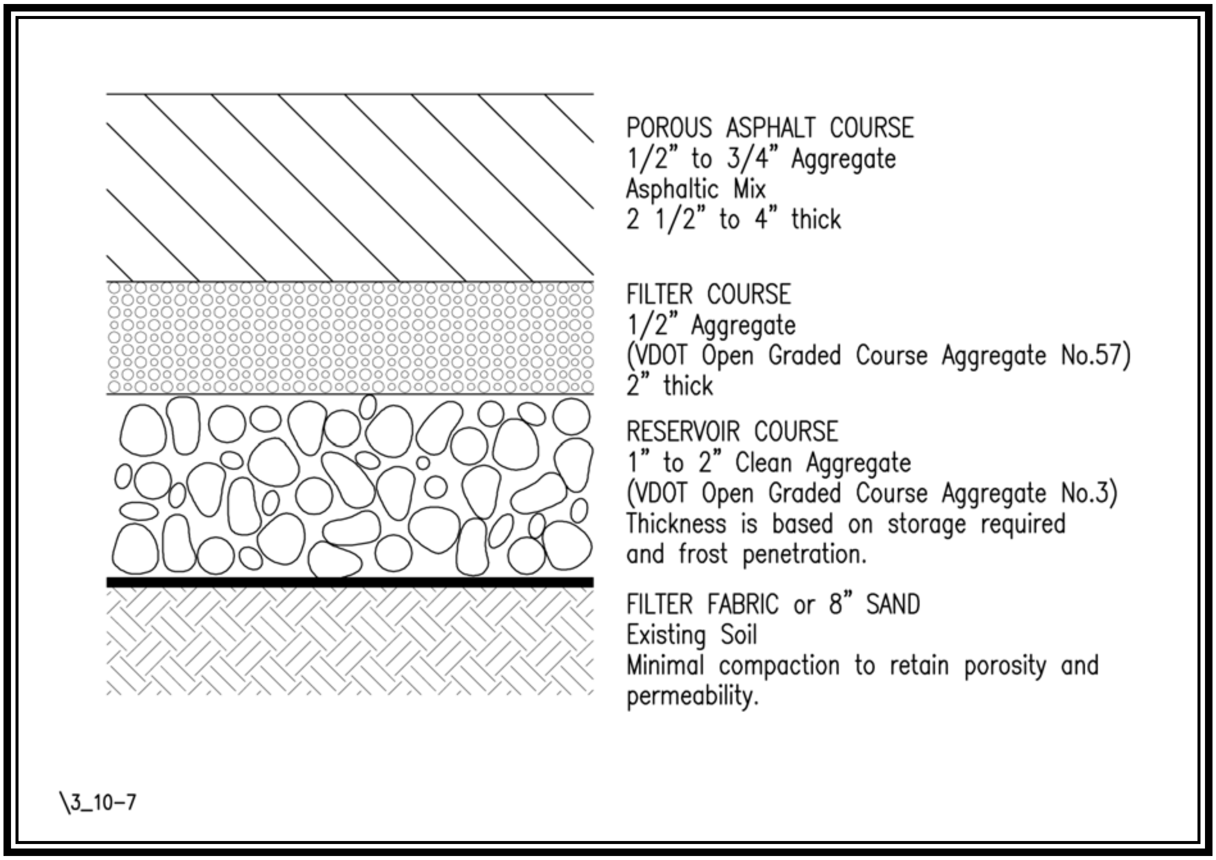
The purpose of porous pavement is to provide water quality enhancement by infiltrating water through the paved surface and stone reservoir and into the underlying soils.

Conditions Where Practice Applies

Porous pavement is applicable as a substitute for conventional asphalt pavement on parking areas and low-traffic roadways if the grades, subsoil drainage characteristics and groundwater table conditions are suitable. Usually, the grades should be very gentle to flat, subsoil should have moderately rapid permeability ($f > 0.52$ *in/hr*) and the depth to the water table or bedrock should be at least 3 feet below the bottom of the stone reservoir. Parking lots, especially fringe or overflow parking areas, are suited for use with this paving material. Porous pavement should generally be installed on sites from 1/4 to 10 acres.

FIGURE 3.10 - 7

Porous Pavement Section



Planning Considerations

Porous pavement functions similar to infiltration trenches and, therefore, has similar planning considerations. Appropriate soil conditions and the protection of groundwater are among the important considerations which may limit its use. Refer to the **Planning Considerations** in **General Infiltration Practices**, **Minimum Standard 3.10** for additional discussion.

Generally, groundwater recharge rates are slightly higher under a porous pavement than under natural conditions, as vegetation is absent and water is not transpired during the summer months. Between 60% and 90% of the annual rainfall volume deposited on a porous pavement percolates into the ground (Washington DOE, 1992.)

It has been shown that porous pavement is more skid-resistant than conventional pavement in rainy weather and that the markings on a porous pavement are easier to see on rainy nights. In addition, studies have suggested that porous asphalt pavement is sufficiently strong and able to withstand freeze-thaw cycles and will last as long, structurally, as conventional pavement.

Typically, porous pavement is slightly more expensive than regular pavement. Additional costs associated with critical installation procedures and the availability of the asphalt mix may be offset by eliminating the need for curb and gutter, inlets, and conveyance systems. Availability is a consideration, since asphalt producers may not be willing to provide porous asphalt for small projects due to the demand for conventional asphalt mixes. For the production of a porous pavement mixture, the asphalt plant must be cleaned out to remove the fines not wanted in the porous mix. The cost of the stone reservoir and filter fabric associated with porous pavement is offset by the amount that would be spent on a stormwater facility elsewhere on the site.

Installation requires a very high level of workmanship throughout the construction process; porous pavement must be handled with great care in order for it to retain its porous qualities. Many pavement contractors and pavement engineers have limited experience in designing and constructing porous pavement. Improper installation can render a porous pavement design inoperative from the outset.

The biggest drawback to porous pavement is its tendency to clog if improperly maintained. Once it is clogged, it may have to be completely replaced since rehabilitating it is difficult and costly. On going maintenance of the pavement surface and specific limitations on the methods of snow and ice removal are often ignored and/or forgotten over time and with transfers of ownership. Clogging of the pavement surface from construction-related erosion can be prevented by waiting until all other phases of construction are complete and vegetation is stabilized before installing the pavement. Clogging of the pavement surface from natural circumstances is best prevented by installing it in areas that do not have highly erodible soils or steep slopes adjacent to the paved area.

Certain features can be incorporated into the design of porous pavement facilities to prolong the effective life of the system. One such feature is to “daylight” the aggregate base along the downslope edge of the pavement, forming a chimney drain into the stone storage under the pavement. The runoff can flow into the stone storage through the chimney drain if the pavement clogs.

If slow infiltration rates in the subgrade exist, porous pavement systems can be designed with an underdrain or collector system. When the collector system has a restriction plate on the outlet that controls the discharge, the stone reservoir can be designed as an underground stone-storage detention facility.

Evidence suggests that pollutants adsorb to the aggregate material, while particulates settle to the bottom of the aggregate layer. However, the target removal efficiency of 50% to 65%, as presented in **Table 3.10-1** for infiltration facilities, is too high for a stone-storage facility. **Therefore, a**

porous pavement facility with a stone storage underdrain system that provides positive drainage will be considered an extended-detention or detention facility. Its target pollutant removal efficiency will be based on the storage and release rate characteristics of these facilities as presented in **Minimum Standards 3.07, Extended-Detention**; and **3.08, Detention Basins**, until more information is collected to support the use of a higher pollutant removal efficiency.

Design Criteria

The purpose of this section is to provide recommendations and minimum criteria for the design of porous pavement intended to comply with the runoff quality requirements of theVirginia Stormwater Management programs.

The general design criteria for the porous pavement stone reservoir area and the underlying soils are the same as for infiltration trenches. Additional design is required for determining the porous pavement thickness. The design of the pavement is dependent on the strength of the sub-base soil, the projected traffic intensities, and the storage capacity of the reservoir and base.

A thorough examination of the site is of primary importance to the proper design and functioning of porous pavement. Soil and climate conditions, expected surface wear, and the use objectives of the porous surface should all be considered before designing the pavement.

The following represents a general list of design elements that should be considered in any porous pavement design:

1. Anticipated traffic intensities, defined by the ***average daily equivalent axle load*** (*EAL*).
2. ***California Bearing Ratio*** (CBR) of the soils.
3. Susceptibility of the soils to frost heave.

Due to the complexity of its design, a step-by-step procedure to engineer a porous pavement section will not be presented in this manual. A professional engineer, with training and experience in porous pavement design and construction, should design the pavement section and supervise during the paving operation.

Specific design requirements for a satisfactory ***porous asphalt pavement*** section equivalent to a conventional pavement design are available through the U. S. Department of Transportation's Federal Highway Administration and through other references listed at the end of this standard.

Specific design requirements for a satisfactory ***porous concrete pavement*** section are available through the Florida Concrete and Products Association, 649 Vassar Street, Orlando, Florida 32804. Other references are also listed at the end of this standard.

Porous Concrete Pavement Construction Specifications

The design criteria and material specifications for ***porous concrete pavement*** are **NOT INCLUDED** in this manual due their extreme complexity. Note that the methods of handling and placing porous concrete are different from other types of concrete. **Only concrete firms and contractors familiar with the intricacies of porous concrete should be used**. For further discussion, refer to **General Pavement Design Criteria** above.

Porous Asphalt Pavement Construction Specifications

The following construction specifications are general and typically represent aspects of design that require fine-tuning based on site conditions. A professional with experience in porous asphalt design should supervise construction to insure proper methods are used.

Overall, widely accepted construction standards and specifications, such as those developed by the USDA Soil Conservation Service or the U.S. Army Corps of Engineers, should be followed where applicable. Further guidance can be found in the Soil Conservation Service's Engineering Field Manual. Specifications for the work should conform to the methods and procedures specified for installing earthwork, concrete, reinforcing steel, pipe, water gates, metal work, woodwork and masonry, as they apply to the site and the purpose of the structure. The specifications should also satisfy any requirements of the local government.

The specifications for the asphalt mix should include:

1. Calculation of void space in the asphalt section.
2. Aggregate type, quality and gradation.
3. Asphalt cement grade in mix.
4. Asphalt content in mix.
5. Mixing temperature.

Construction of a porous asphalt pavement should also be in conformance with the following (adapted from Construction Sspecifications for the City of Rockville, Maryland:

Stabilization

To preclude premature clogging and/or failure, porous asphalt pavement should not be placed into service until all of the surface drainage areas contributing to the paved area have been effectively stabilized. Refer to the VESCH 1992 edition, for stabilization requirements.

Subgrade Preparation

1. Alter and refine the grades as needed to bring subgrade to required grades and sections as shown in the drawings.

2. The type of equipment used in subgrade preparation should not cause undue subgrade compaction. (Use tracked-equipment or equipment with oversized rubber tires **Do Not use standard rubber tire equipment**.) Traffic over the subgrade should be kept to a minimum. Where fill material is required, it should be compacted to a density equal to the undisturbed subgrade. Inherent soft spots should be corrected.

Trench Bottom

The trench bottom may be lined with filter fabric or an *8* inch layer of sand (VDOT Fine Aggregate, Grading A or B), based on the geotechnical and pavement design recomendations.

Reservoir course

1. The stone reservoir course aggregate should be 1 to 2 inch diameter clean, washed, crushed stone meeting VDOT specifications (Open Graded Course Aggregate No. 3).

2. The stone reservoir thickness (depth) is dependent on the storage volume requirements (water quality volume, quantity control volumes, etc.).

Filter Course

1. The filter course aggregate should be 1/2-inch diameter clean, washed, crushed stone, meeting VDOT specifications (Open-graded Course Aggregate No. 57).

2. The filter course thickness should be 2 inchs.

Porous Asphalt Surface Course

1. The surface course should be laid directly over the aggregate base course and should be laid in one lift.

2. The laying temperature should be between 230EF and 260EF, with a minimum air

temperature of 50EF, to make sure that the surface does not stiffen before compaction.

3. Compaction of the surface course should be completed while the surface is cool enough to resist a 10-ton roller. One or two passes of the roller are required for proper compaction. More rolling could cause a reduction in the surface course porosity.

4. The mixing plant should certify to the aggregate mix, the abrasion loss factor, and the asphalt content in the mix. The asphalt mix should be tested for its resistance to stripping by water using ASTD 1664. If the estimated coating area is not above 95%, antistripping agents should be added to the asphalt.

5. The mix should be transported to the site in a clean vehicle with smooth dump beds sprayed with a non-petroleum release agent. The mix should be covered during transportation to control cooling.

6. The asphalt mix should be 5.5 to 6% of dry aggregate by7 weight.

7. The asphalt's grade should meet AASHTO Specification M-20; 85 to 100% penetration road asphalt as a binder in the western part of the state, 65 to 80% in the piedmont area, and 50 to 65% in southeastern Virginia.

8. The aggregate grading should be as specified in **Table 3.10-3**.

Protection

After final rolling, no vehicular traffic of any kind should be permitted on the pavement until cooling and hardening has taken place, and never less than 6 hours (preferably 24 to 48 hours). All construction related traffic should be routed around or away from the porous pavement.

Workmanship

1. Work should be completed with expertise throughout the process and without staining or damage to other permanent work.

2. The transition between existing and new paving work should be neat and flush.

3. Finished paving should be even, without pockets, and graded to elevations shown.

4. All minor surface projections and edges adjoining other materials should be ironed smoothly to grade.

Certification

An appropriate professional should certify that these specifications were followed.

TABLE 3.10 - 3

*Porous (Open-graded) Asphalt Concrete Formulation**

PROBABLE PARTICLE DATA						
Material	**Screen**	**Weight** *%*	**Volume** *%*	**Width** *mm*	**Weight** *g*	**No. In 100g of Asphalt Concrete**
Aggregate	**Through ½**	**2.8**	**2.2**	**10.7**	**1.667**	**1.7**
	Through 3/8	**59.6**	**46.3**	**8.0**	**.697**	**85.5**
	Through #4	**17.0**	**13.3**	**4.0**	**.087**	**195.4**
Sub-Total Coarse Aggregate		**79.4**	**61.8**			**282.6**
	Through # 8	**2.8**	**2.2**	**2.0**	**.0109**	**255.6**
	Through #16	**10.4**	**8.0**	**1.0**	**.00136**	**7647.**
	Through 200	**1.9**	**1.5**	**.06**	**.000294**	**6462.**
Asphalt		**5.5**	**10.5**			
Air		**0**	**16.0**			
TOTAL		**100.0**	**100.0**			

** Source: City of Rockville, Maryland (1982).*

Maintenance and Inspections

The following maintenance and inspection guidelines are not intended to be all-inclusive. Specific applications may require other measures not discussed here.

Inspection Schedule

The observation well should be checked quarterly and after every large storm event. It is recommended that a log book be maintained showing the depth of water in the well during each inspection in order to determine the rate at which the facility dewaters after runoff producing storms events. Once the performance characteristics of the structure have been verified, the monitoring schedule can be reduced to an annual basis, unless the performance data suggest that a more frequent schedule is required.

Maintenance

The surface of porous asphalt pavement must be cleaned regularly to prevent it from becoming clogged by fine material. This cleaning is best accomplished through the use of a vacuum cleaning street sweeper, followed by high pressure water washing. Outside of regular cleaning, porous pavement requires maintenance similar to that of regular pavement. In times of heavy snowfall, however, application of abrasive material should be closely monitored to avoid clogging problems once the snow and ice has melted. There are no maintenance measures designed to repair fully clogged porous pavement, other than replacement.

Design Procedures

The following design procedure represents a generic list of the steps typically required for the design of an infiltration trench.

1. Determine if the anticipated development conditions and drainage area are appropriate for a porous pavement application.

2. Determine if the soils (permeability, bedrock, water table, Karst, etc.) and site topographic conditions (slopes, etc.) are appropriate for a porous pavement application.

3. Locate the porous pavement section on the site within the topographic constraints.

4. Determine the drainage area for the porous pavement and calculate the required water quality volume.

5. Evaluate the hydrology of the contributing drainage area to determine peak rates of runoff.

6. Design the porous pavement stone reservoir:
    - design infiltration rate, $f_d = 0.5\,f$
    - max. storage time T_{max} = 48 hours
    - max. storage depth, d_{max}
    - stone backfill of clean aggregate (1.5" to 3.5") VDOT No. 1 Open-graded Course Aggregate
    - filter gravel layer - two inches of clean aggregate (1/2") VDOT No. 57 Open-graded Course Aggregate
    - sand layer on trench bottom (8 inche), or filter fabric, per geotechnical and pavement design recommendations
    - Filter fabric on trench sides and top (not on trench bottom) keyed into trench
    - Overflow channel or large storm bypass
    - Observation well

7. Provide pavement section design and material specifications.

8. Provide sequence of construction.

9. Provide maintenance and inspection requirements.

REFERENCES

(Compiled from Standards and Specifications for Infiltration Practices, Maryland Department of Natural Resources, 1987)

Bentall, R. Methods of Collecting and Interpreting Ground Water Data. U.S. Geological Survey, Water Supply Paper 1544-H, 1963, 97 pp.

Bianchi, W. C., and D. C. Muckel. Ground Water Recharge Hydrology. ARS 41-161, U.S. Department of Agriculture, 1970, 62 pp.

Cedergreen, H. R. Seepage, Drainage, and Flow Nets. New York: John Wiley and Sons, Inc., 1967.

Davis, S. N., and R. J. DeWiest. Hydrogeology. New York: John Wiley and Sons, Inc., 1966.

Ferris, J. G., D. B. Knowles, R. H. Brown, and R. W. Stallman. Theory of Aquifer Tests. U.S. Geological Survey, Water Supply Paper No. 1536-E.

Florida Concrete and Products Association. Design Manual. Orlando, FL.

Galli, John. Analysis of Urban BMP Performance and Longevity. Metropolitan Washington Council of Governments, 1992.

Hannon, J. B. Underground Disposal of Storm Water Runoff, Design Guidelines Manual. The California Department of Transportation in cooperation with the Federal Highway Administration, U.S. Department of Transportation, Washington, DC (FHWA-TS-80-218), February 1980.

Maryland Department of Natural Resources. Standards & Specifications for Infiltration Practices. 1987.

Northern Virginia Planning District Commission. Northern Virginia BMP Handbook. 1992.

Pettyjohn, W. A. Introduction to Artificial Ground Water Recharge. Robert S. Kerr Environmental Research Laboratory, U.S. Environmental Protection Agency. Worthington, Ohio: National Waterwell Association, 1981, 44 pp.

Rawls, W. J., D. L. Brakensiek, and K. E. Saxton. “Estimation of Soil Properties.” Transactions of the American Society of Agricultural Engineers, Vol. 25, No. 5. 1982. p. 1316-1320.

Scheuler, T. R. Controlling Urban Runoff. Metropolitan Washington Council of Governments, 1987.

Scheuler, T. R., P. A. Kumble, and M. A. Heraty. A Current Assessment of Urban Best Management Practices. Metropolitan Washington Council of Governments, 1987.

Schmidt, C. J., and E.V. Clements. Reuse of Municipal Wastewater for Ground Water Recharge. U. S. Environmental Protection Agency, 1977, 183 pp.

Smith, R. W., J. M. Rice, and S. R. Spelman. Design of Open Graded Asphalt Friction Courses. Federal Highway Administration, U. S. Department of Transportation, FHWA-RD-74-2, 1974.

Soil Conservation Service, Engineering Division. Technical Release No. 36. Ground Water Recharge. U. S. Department of Agriculture, 1967, 22 pp.

Soil Conservation Service. National Engineering Handbook, Section 18 Ground Water. U. S. Department of Agriculture, 1968.

Soil Conservation Service. National Engineering Handbook, Section 8, Engineering Geology. U. S. Department of Agriculture, 1978.

Thelen, E., and L. F. Howe. Porous Pavement. Philadelphia, PA: The Franklin Institute Press, 1978.

Thelen, E., et al. Investigation of Porous Pavements for Urban Runoff Control. Franklin Institute Research Laboratories for the U.S. Environmental Protection Agency, NTIS PB-227-5. Springfield, VA, 1972.

Todd, D. K. Ground Water Hydrology. New York: John Wiley and Sons, Inc., 1959.

U. S. Environmental Protection Agency, Office of Water Programs Operations. Design Manual: Onsite Wastewater Treatment and Disposal Systems. U.S. EPA 20460, October 1980.

Virginia Department of Conservation and Recreation. Virginia Erosion and Sediment Control Handbook (VESCH). Richmond, Virginia: 1992.

Virginia State Water Control Board. Best Management Practices Handbook: Urban: Planning Bulletin 321. Richmond, Virginia, 1979.

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

Wenzel, L. K. Methods of Determining Permeability of Water Bearing Materials. U. S. Geological Survey, Water Supply Paper 887, 1942.

Chapter 3.10

Surface Infiltration Trench. Note grass strip pre-treatment holds heavier particulate pollutants within paved area.

Porous Pavement Infiltration. Testing new pavement installation. Note: steady flow passes through pavement and into stone storage below with minimal spread.

General Infiltration Practices

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Infiltration Basin serves as landscaped pedestrian area during dry periods.

Infiltration Trench with concrete parking pavers in office park setting.

General Infiltration Practices