Protocol 4 Infiltration System Design and Construction Guidelines

A. Purpose of this Protocol

This protocol (Protocol 4) provides technical information and design guidance common to all infiltration BMPs.

This protocol provides the designer with specific guidelines for the design, construction, and long-term performance of infiltration BMPs. These guidelines fall into three categories:

1. Site conditions and constraints
2. Design considerations
3. Construction requirements

Successful BMP implementation is dependent on careful consideration of site conditions, thoughtful design, and quality construction. These guidelines provide important information and instruction.

B. Infiltration BMPs and Their Purpose

The phrase "infiltration BMPs" describes a wide range of stormwater management practices aimed at infiltrating some fraction of stormwater runoff from developed surfaces into the soil horizon and potentially into deeper groundwater. The major infiltration strategies are:

- Pervious Pavement (Chapter 5.3.1)
- Infiltration Bed (Chapter 5.3.2)
- Infiltration Trench (Chapter 5.3.3)
- Bioretention (Bioinfiltration, Rain Garden) (Chapter 5.3.4)
- Vegetated Swales (Biofilters-Grass Swales) (Chapter 5.3.5)
- Vegetated Filter Strips (Biofilters, Grass Strips) (Chapter 5.3.6)
- Infiltration Berms (Chapter 5.3.7)
- Other BMPs that support infiltration not covered in this guide

Infiltration BMPs are one of the most beneficial approaches to stormwater management for a variety of reasons, including:

- Reduction of the peak rate of runoff
- Reduction of the volume of runoff

- Removal of a significant portion of the particulate-associated pollutants and some portion of the solute pollutants
- Recharge of groundwater and maintenance of stream base flow

Infiltration BMPs attempt to replicate the natural hydrologic regime. During periods of rainfall, infiltration BMPs reduce the volume of runoff and help to mitigate potential flooding events. During periods of reduced rainfall, this recharged water serves to provide base flow to streams and maintain in-stream water quality. Qualitatively, infiltration BMPs are known to remove nonpoint source pollutants from runoff through a complex mix of physical, chemical, and biological removal processes. Infiltration promotes maintenance of the natural temperature regimes of stream systems (cooler in summer, warmer in winter), which can be critical to the aquatic ecology. Because of the ability of infiltration BMPs to reduce the volume of runoff, there is a corresponding reduction in erosive "bank full" conditions and downstream erosion and channel morphology changes.

Infiltration BMPs are designed to infiltrate some portion of runoff during every runoff event. During small storm events, a large percentage of the runoff may infiltrate, whereas during large storm events, the volume that infiltrates may be only a small portion of the total runoff. However, because most of the rainfall in Tennessee occurs in small (less than 1-inch) rainfalls, the annual benefits of an infiltration system may be significant.

C. Infiltration System Guidelines

1. Site Conditions and Constraints

a) It is desirable to **maintain a 2-foot clearance above the regularly occurring seasonally high water table**. This reduces the likelihood that temporary groundwater mounding will affect the system, and provides sufficient distance for water movement through the soil to allow adequate pollutant removal. Some minor exceptions may be allowed for very shallow systems and on-grade systems, filter strips, buffers, etc.

b) **A minimum depth to bedrock (including weathered bedrock) of 2 feet should be maintained to ensure adequate pollutant removal**. In special circumstances, filter media may be employed to remove pollutants if adequate soil mantle does not exist. Generally, the bottom of an infiltration system should provide at least 2 feet of soil mantle.

c) **Soils underlying infiltration BMPs should have measured infiltration rates between 0.1 and 10 inches per hour**. In most development programs, this will result in reasonably sized infiltration systems. Where soil permeability is extremely low, infiltration may still be possible, but the surface area required could be large and therefore other volume reduction methods may be warranted. Soils with rates in excess of 6 inches per hour may be excessively well-drained and require an additional soil buffer (such as an organic layer over the bed bottom). Such situations should be evaluated on a case-by-case basis.

d) **Infiltration BMPs should be sited so that risk to groundwater quality is minimized**. Systems should be located at least 50 feet from individual water supply wells and 100 feet from community or municipal water supply wells. Horizontal separation distances or buffers from special geologic features, such as fractures, traces, and faults, may also be appropriate depending on water supply sources and should be evaluated on a case-by-case basis.

e) **Infiltration at hot areas should include consideration of site conditions**. Where there is a likelihood of spills of hazardous substances, such as fueling stations, infiltration systems should not be employed. However, the entire project site should not be excluded from infiltration, only those areas subject to spills or storage of hazardous substances. If structural spill containment procedures, such as containment areas, are employed, infiltration may be feasible. Each site should be evaluated on a case-by-case basis.

f) **Brownfield sites must be evaluated on a case-by-case basis.** In many situations, depending on the nature of past uses and potential contamination, infiltration will not adversely affect site conditions or water quality. However, sites with known soil contamination issues may not be suitable for infiltration. The designer should coordinate with the City and TDEC requirements on a case-by-case basis.

g) **Infiltration BMPs should be sited so that they present no threat to subsurface structures**. These include building foundations and basements, certain utilities, existing subsurface structures, etc. (See Protocol 1, Infiltration BMP Setbacks from Structures, and Protocol 2, BMP Coordination with Other Utilities, for additional information.)

In general, soils of hydrologic soil group D will not be suitable for infiltration. Similarly, areas of floodplains and areas in proximity to wetlands and streams generally will not be suitable for infiltration (due to a high water table and/or proximity to underlying rock formations). For developing areas previously used for agricultural purposes, the designer should consider the past patterns of land use. Areas that were suitable for cultivation will likely be suitable for some level of infiltration. Areas that were excluded from cultivation often indicate locations that are too wet or too rocky, and will likely not be suitable for infiltration.

2. <u>Design Considerations</u>

a) **Do not infiltrate in compacted fill**. Infiltration in native soil without prior fill or disturbance is preferred but not always possible. Areas that have experienced historic disturbance or fill are suitable for infiltration provided that sufficient time has elapsed and soil testing indicates infiltration is feasible. Fill that was placed more than 10 years ago and that has been subject to rainfall and weathering may be suitable for infiltration. In disturbed areas, it may be necessary to infiltrate at a depth beneath soils that have previously been compacted by construction methods or long periods of mowing, i.e., 12 to 18 inches below the existing surface grade.

b) **A level infiltration area is preferred**. Bed bottoms should always be graded into the existing soil mantle, with terracing as required to construct flat-bottom structures. Sloped bottoms tend to pool and concentrate water in small areas, reducing the overall rate of infiltration and longevity of the BMP. Infiltration areas should be flat, or nearly so (less than a 1 percent slope). Orienting infiltration BMPs along the existing contours will facilitate level bottoms and reduce the amount of cut/fill required for construction.

c) **Preserve the soil mantle to the maximum extent possible and minimize excavation**. Soils that do not need to be disturbed for the building program should be left undisturbed and protected (Chapter 5.2.1). Macropores can provide a significant mechanism for water movement in infiltration systems, and the extent of macropores often decreases with depth. Maximizing the soil mantle increases pollutant removal capacity and reduces concerns about groundwater mounding. Therefore, excessive excavation for the construction of infiltration systems is strongly discouraged.

d) **Isolate "hot areas."** Site plans that include "hot areas" must be considered in BMP design. Hot areas are most often associated with industrial uses, past contamination, and high traffic, such as gasoline stations and vehicle maintenance areas. These areas may be suitable for infiltration BMPs if designed with management measures to address potential contamination issues. This may include structural spill containment measures prior to infiltration BMPs, oil water separators, etc. Hot areas must be evaluated on a case-by-case basis.

Additionally, certain land uses may have unusually high levels of sediment and other pollutants. Examples include high-intensity commercial uses (fast-food restaurants, convenience stores, etc.), especially areas around dumpsters and material handling areas and loading docks. The potentially high pollutant loadings warrant consideration in BMP design, and pretreatment may be required. Pretreatment devices that operate effectively in conjunction with infiltration BMPs include grass swales, vegetated filter strips, settling chambers, oil/grit separators, sediment sumps and traps, and water quality inserts. The pollutants of greatest concern, site by site, should guide selection of pretreatment options depending upon the nature and extent of the land development under consideration. Selection of pretreatment techniques will vary depending upon whether pollutants are of a particulate (sediment, phosphorus, metals, etc.) versus soluble (nitrogen and others) nature. Types of pretreatment (i.e., filters) should be matched with the nature of the pollutants expected to be generated.

e) **Consider the loading ratio of impervious area to bed bottom area**. One of the more common reasons for infiltration system failure is the design of a system that attempts to infiltrate a substantial volume of water in a very small area. Infiltration systems work best when the water is “spread out.” The loading ratio describes the ratio of impervious drainage area to infiltration area, or the ratio of total drainage area to infiltration area. In general, the following loading ratio guidelines are recommended:

For 1-inch rainfall or less:

- A maximum impervious loading ratio of 10:1 relating impervious drainage area to infiltration area
- A maximum total loading ratio of 20:1 relating total drainage area to infiltration area

For storms greater than 1 inch and less than or equal to1.6 inches:

- A maximum impervious loading ratio of 8:1 relating impervious drainage area to infiltration area
- A maximum total loading ratio of 16:1 relating total drainage area to infiltration area

The above loading ratios are **guidelines** intended to assist the designer in achieving successful BMP implementation. Loading ratios rarely fit neatly into these exact ratios, as the BMP location will be a function of location opportunities (based on topography, soils, etc.) and land use. However, exceeding the loading ratios for impervious area should be done in coordination with input from the City and with careful consideration of the nature of the runoff. For example, BMPs that receive “clean” roof runoff may be less susceptible to clogging than BMPs that receive sediment-laden road runoff, and a higher loading ratio may be warranted if soil conditions are suitable.

f) **Limit the depth of water**. The total depth of standing surface water generally should not be greater than 2 feet above an infiltration area to avoid excessive pressure and potential sealing of the bed bottom. Typically, water depth is limited by the loading ratio and drawdown time and is not an issue.

g) **Consider drawdown time**. In general, infiltration BMPs must be designed so that the system is completely drained within 72 hours. Table D-1 provides a summary of volume infiltration potential within the required 72-hour drawdown time for a range of infiltration rates.

Table D-1. Summary of Volume Infiltration Potential

Infiltration Rate ($^{in.}/_{hr.}$)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Volume Infiltrated in 72 hours (in.)	7.2	14.4	21.6	28.8	36.0	43.2	50.4	57.6	64.8	72.0
Drawdown Time at 1.0 inch (hr.)	10.0	5.0	3.3	2.5	2.0	1.7	1.4	1.3	1.1	1.0
Drawdown Time at 10.0 inches (hr.)	100.0	50.0	33.3	25.0	20.0	16.7	14.3	12.5	11.1	10.0
Drawdown Time at 1.6 inches (hr.)	16.0	8.0	5.3	4.0	3.2	2.7	2.3	2.0	1.8	1.6
Drawdown Time at 12.8 inches (hr.)	128.0	64.0	42.7	32.0	25.6	21.3	18.3	16.0	14.2	12.8

h) **Design infiltration BMPs with a positive overflow** that discharges excess volume in a non-erosive manner, and allows for controlled discharge during extreme rainfall events or frozen bed conditions. Infiltration BMPs should never be closed systems dependent entirely upon infiltration. Large storm events must be able to "overflow." Overflow systems should have the capacity to convey the flow from the 25-year, 5-minute rainfall intensity.

i) **Incorporate geotextiles into the design as necessary in certain infiltration BMPs**. Infiltration BMPs that are subject to soil movement and deposition must be constructed with suitably well-draining non-woven geotextiles to prevent movement of fines and sediment into the infiltration system. The designer is encouraged to exercise caution and use geotextiles as necessary at the soil/BMP interface.

:tile

j) **Avoid severe slopes (>20 percent) and toes of slopes**, where possible. Specific onsite investigations by experienced personnel need to be made to determine acceptability of each case.

3. <u>Construction Requirements</u>

a) **Do not compact soil infiltration beds during construction**. Prohibit heavy equipment from the infiltration area and minimize other traffic. Equipment should be limited to vehicles that will cause the least compaction, such as tracked vehicles.

b) **Protect the infiltration area from sediment until the surrounding site is <u>completely</u> stabilized**. Methods to prevent sediment from washing into BMPs should be clearly shown on plans. Geotextile used as a bed bottom liner should be extended several feet beyond the bed and folded over the edge to protect from sediment wash into the bed during construction, and then trimmed. Runoff from construction areas should never be allowed to drain to infiltration BMPs. This can usually be accomplished by diversion berms and immediate vegetative stabilization. The infiltration area may be used as a temporary sediment trap or basin during earlier stages of construction. However, if an infiltration area is also to be used as a temporary sediment basin, excavation should be limited to within 1 foot of the final bottom invert of the infiltration BMP to prevent clogging and compacting of the soil horizon, and final grade should be removed when the contributing site is fully stabilized. All infiltration BMPs should be finalized at the end of the construction process, when upstream soil areas have a dense vegetative cover (at least 70 percent).

c) **Provide thorough <u>construction oversight</u>**. Long-term performance of infiltration BMPs is dependent on the care taken during construction. Plans and specifications must be followed precisely. The designer is encouraged to meet with the contractor to review the plans and construction sequence prior to construction, and to inspect the construction at regular intervals and prior to final acceptance of the BMP.

d) **Provide quality control of materials**. As with all BMPs, the final product is only as good as the materials and workmanship that went into it. The designer is encouraged to review and approve materials and workmanship, especially as related to aggregates, geotextiles, soil and topsoil, and vegetative materials.

D. Common Causes of Infiltration BMP "Failures"

The concept of failure is simple – a design no longer provides the benefit or performance anticipated. With respect to stormwater infiltration BMPs, the term requires some qualification, since the net result of "failure" may be a reduction in the volume of runoff anticipated or the discharge of stormwater with excessive levels of pollutants. Where the system includes built structures, such as porous pavements, failure may include loss of structural integrity for the wearing surface, whereas the infiltration function may continue uncompromised. For infiltration systems with vegetated surfaces, such as play fields or rain gardens, failure may include the inability to support surface vegetation, caused by too much or too little water.

The primary causes of reduced performance appear to be:

a) Poor construction techniques, especially soil compaction/smearing, which result in significantly reduced infiltration rates

b) A lack of site soil stabilization prior to the BMP receiving runoff, which greatly increases the potential for sediment clogging from contiguous land surfaces

c) Inadequate pretreatment, especially of sediment-laden runoff, which can cause a gradual reduction of infiltration rates

d) Lack of proper maintenance (erosion repair, revegetation, removal of detritus, catch basin cleaning, vacuuming of pervious pavement, etc.), which can reduce the longevity of infiltration BMPs

e) Inadequate design

Infiltration systems should be designed such that failure of the infiltration component does not completely eliminate the peak rate attenuation capability of the BMP. Because infiltration BMPs are designed to infiltrate small, frequent storms, the loss or reduction of this capability may not significantly impact the storage and peak rate mitigation of the BMP during extreme events.