

## **APPENDIX B**

### **SITE SOIL EVALUATION AND SOIL INFILTRATION TESTING**

Source: Pennsylvania Stormwater Best Management Practice Manual, December 2006.

## SITE SOIL EVALUATION AND SOIL INFILTRATION TESTING

### A. Purpose of this Protocol

The purpose of the *Site Evaluation and Soil Infiltration Testing Protocol* is to describe evaluation and field testing procedures to:

- a. Determine if infiltration BMPs are suitable at a site, and at what locations.
- b. Obtain the required data for infiltration BMP design.

### B. When to Conduct Testing

The site development process outlined in Chapters 4 and 5 of the Pennsylvania Stormwater Management Best Management Practices Manual, December 2006, as amended (“Manual”) describe a process for site development and BMPs. Soil Evaluation and Investigation shall be conducted early in the preliminary design of the project so that information developed in the testing process can be incorporated into the design. The Soil Evaluation and Investigation shall be conducted prior to development of the preliminary plan. The design engineer should possess a preliminary understanding of potential BMP locations prior to testing. Prescreening test may be carried out in advance of site potential BMP locations.

### C. Who Should Conduct Testing

Qualified professionals who can substantiate by qualifications/experience their ability to carry out the evaluation shall conduct the test pit soil evaluations. A professional, experienced in observing and evaluating soils conditions is necessary to ascertain conditions that might affect BMP performance, which can not be thoroughly assessed with the testing procedures. Such professionals must conduct these evaluations in risk areas, and areas indicated in the Manual as non-preferred locations for testing or BMP implementation.

### D. Importance of Stormwater BMP Areas

Sites are often defined as unsuitable for infiltration BMPs and soil based BMPs due to proposed grade changes (excessive cut or fill) or lack of suitable areas. Many sites will be constrained and unsuitable for infiltration BMPs. However, if suitable areas exist, these areas must be identified early in the design process and not be subject to a building program that precludes infiltration BMPs. An exemption will not be permitted for development of suitable soils otherwise exist for infiltration.

### E. Safety

As with all field work and testing, attention must be given to all applicable OSHA regulations related to earthwork and excavation. Digging and excavation shall not be conducted without adequate notification through the Pennsylvania One Call system (**PA One Call** 1-800-242-1776 or [www.paonecall.org](http://www.paonecall.org)). Excavations shall not be left unsecured and unmarked, and all applicable authorities must be notified prior to any work.

## **INFILTRATION TESTING: A MULTI-STEP PROCESS**

Infiltration Testing is a four-step process to obtain the necessary data for design of the stormwater management plan. The four steps include:

### 1. Background Evaluation

- Based on available published and site specific data
- Includes consideration of proposed development plan
- Used to identify potential BMP locations and testing locations
- Prior to field work (desktop)
- On-site screening test

### 2. Test Pit (Deep Hole) Observation

- Includes Multiple Testing Locations
- Provides an understanding of sub-surface conditions
- Identifies limiting conditions

### 3. Infiltration Testing

- Must be conducted onsite
- Different testing methods available
- Alternate methods for – additional – Screening and Verification testing

### 4. Design Considerations

- Determination of suitable infiltration rate for design calculations
- Consideration of BMP drawdown
- Consideration of peak rate attenuation

## **Step 1. Background Evaluation**

Prior to performing testing and developing a detailed site plan, existing conditions at the site must be inventoried and mapped including, but not limited to:

- Existing mapped individual soils and USDA Hydrologic Soil Group classifications.
- Existing geology, including the location of any dikes, faults, fracture traces, solution cavities, landslide prone strata, or other features of note.
- Existing streams (perennial and intermittent, including intermittent swales) water bodies, wetlands, hydric soils, floodplains, alluvial soils, stream classifications, headwaters and 1<sup>st</sup> order streams.
- Existing topography, slope, and drainage patterns.
- Existing and previous land uses.
- Other natural or man-made features or conditions that may impact design, such as past uses of site, existing nearby structures (building, walls), etc.

A sketch plan or preliminary layout plan for development should be evaluated, including:

- Preliminary grading plan and areas of cut and fill.
- Location and water surface elevation of all existing and location of proposed water supply sources and wells.
- Location of all existing and proposed onsite wastewater systems.
- Location of other features of note such as utility right-of-ways, water and sewer lines, etc.
- Existing data such as structural borings, drillings, and geophysical testing.
- Proposed location of development features (buildings, roads, utilities, walls, etc.). In Step 1, the designer should determine the potential location of infiltration BMPs. The approximate location of these BMPs should be identified on the proposed development plan and serve as the basis for the location and number of tests to be performed onsite.

**Important:** If the proposed development program is located on areas that may otherwise be suitable for BMP location, or if the proposed grading plan is such that potential BMP locations are eliminated, the designer must revisit the proposed layout and grading plan and adjust the development plan as necessary. Development on areas suitable for infiltration BMPs may *not* preclude the use of BMPs for volume reduction and groundwater recharge.

## **Step 2. Test Pits (Deep Holes)**

A Test Pit (Deep Hole) allows visual observation of the soil horizons and overall soil conditions both horizontally and vertically in that portion of the site. An extensive number of Test Pit observations can be made across a site at a relatively low cost and in a short time period. The use of soil borings as a substitute for Test Pits is not permitted as visual observation is narrowly limited in a soil boring and the soil horizons cannot be observed in-situ, but must be observed from the extracted borings. Borings and other procedures, however, might be suitable for initial screening to develop a plan for testing, or verification testing.

A Test Pit consists of a backhoe-excavated trench, two and one half (2½) to three (3) feet wide, to a depth of between seventy two (72) inches and ninety (90) inches, or until bedrock or fully saturated conditions are encountered. The trench should be benched at a depth of two (2) to three (3) feet for access and/or infiltration testing.

At each Test Pit, the following conditions shall be noted and described. Depth measurements shall be described as depth below the ground surface:

\_\_\_ Soil horizons (upper and lower boundary)

\_\_\_ Soil texture and color for each horizon

\_\_\_ Color patterns

\_\_\_ Depth to water table

\_\_\_ Depth to bedrock

\_\_\_ Observance of pores or roots (size, depth)

- \_\_\_ Estimated type and percent coarse fragments
- \_\_\_ Hardpan or limiting layers
- \_\_\_ Strike and dip of horizons (especially lateral direction of flow at limiting layers)
- \_\_\_ Additional comments or observations

The Sample Soil Log Form at the end of this protocol may be used for documentation of each Test Pit.

At the designer's discretion, soil samples may be collected at various horizons for additional analysis. Following testing, the test pits must be refilled with the original soil and the surface replaced with the original topsoil. A Test Pit should *never* be accessed if soil conditions are unsuitable for safe entry, or if site constraints preclude entry.

It is important that the Test Pit provide information related to conditions at the bottom of the proposed infiltration BMP. If the BMP depth will be greater than ninety (90) inches below existing grade, deeper excavation will be required. However, *such depths are discouraged, especially in Karst topography*. Except for surface discharge BMPs (filter strips, etc.) the designer is cautioned regarding the proposal of systems that are significantly lower than the existing topography. The suitability for infiltration may decrease, and risk factors are likely to increase. *Locations that are not preferred* for testing *and* subsurface infiltration BMPs include swales, the toe of slopes for most sites, and soil mantels of less than three feet in Karst topography.

The designer and contractors shall limit grading and earthwork to reduce site disturbance and compaction so that a greater opportunity exists for testing and stormwater management.

The number of Test Pits varies depending on site conditions and the proposed development plan. General guidelines are as follows:

- For single-family residential subdivisions with on-lot BMPs, one test pit per lot is recommended, preferably within twenty five (25) feet of the proposed BMP area. Verification testing should take place when BMPs area sited at greater distances.
- For multi-family and high density residential developments, one test pit per BMP area or acre is recommended.
- For large infiltration areas (basins, commercial, institutional, industrial, and other proposed land uses), multiple test pits should be evenly distributed at the rate of four (4) to six (6) tests per acre of BMP area.

The recommendations above are guidelines. Additional tests will be required if local conditions indicate significant variability in soil types, geology, water table levels, bedrock, topography, etc. Similarly, uniform site conditions may indicate that fewer test pits are necessary. Excessive testing and disturbance of the site prior to construction is not recommended.

### **Step 3. Infiltration Tests/Permeability Tests**

A variety of field tests exist for determining the infiltration capacity of a soil. Laboratory tests are strongly discouraged, as a homogeneous laboratory sample does not represent field conditions. Infiltration tests should be conducted in the field. Tests should not be conducted in the rain or within twenty four (24) hours of a significant rainfall events (>0.5 inches), or when the temperature is

below freezing. However, the preferred testing *is* between January and June, the wet season. This is the period when infiltration is likely to be diminished by saturated conditions. Percolation tests carried out between June 1 and December 31 shall use a twenty four (24) hour presoaking before the testing. This procedure is not required for infiltrometer testing, or permeometer testing.

At least one test shall be conducted at the proposed bottom elevation of an infiltration BMP, and a minimum of two tests per Test Pit is recommended. More tests may be warranted if the results for first two tests are substantially different. The highest rate (inches/hour) for test results should be discarded when more than two are employed for design purposes. The geometric mean should be used to determine the average rate following multiple tests.

Based on observed field conditions, the proposed bottom elevation of BMP may be revised. Infiltration testing should be proposed to adjust locations and depths depending upon observed conditions.

Methodologies discussed in this protocol include:

- Double-ring infiltrometer tests.
- Percolation tests (such as for onsite wastewater systems and described in PA Code Chapter 73).

There are differences between the two methods. A double-ring infiltrometer test estimates the vertical movement of water through the bottom of the test area. The outer ring helps to reduce the lateral movement of water in the soil. A percolation test allows water movement through both the bottom and sides of the test area. For this reason, the measured rate of water level drop in a percolation test must be adjusted to represent the discharge that is occurring on both the bottom and sides of the percolation test hole.

For *infiltration basins*, an infiltration test should be completed with an infiltrometer (not percolation test) to determine the saturated hydraulic conductivity rate. This precaution is taken to account for the fact that only the surface of the basin functions to infiltrate, as measured by the test. Alternatively, permeability test procedures that yield a saturated hydraulic conductivity rate can be used (see formulas developed by Elirick and Reynolds (1992), or others for computation of hydraulic conductivity and saturated hydraulic conductivity).

Other testing methodologies and standards that are available but not discussed in detail in this protocol include (but are not limited to):

- Constant head double-ring infiltrometer.
- Testing as described in the Maryland Stormwater Manual Appendix D.1 using five (5) inch diameter casing.
- ASTM 2003 Volume 4.08, Soil and Rock (I): Designation D3385-03, Standard Test Method for Infiltration Rate of Soils in Field Using a Double-Ring Infiltrometer.
- ASTM 2002 Volume 4.09, Soil and Rock (II): Designation D 5093.90, Standard Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring.
- Guelph Permeameter.
- Constant Head Permeameter (Amoozemeter).

**a. Methodology for Double-Ring Infiltrometer Field Test**

A Double-ring Infiltrometer consists of two concentric metal rings. The rings are driven into the ground and filled with water. The outer ring helps to prevent divergent flow. The drop in water level or volume in the inner ring is used to calculate an infiltration rate. The infiltration rate is determined as the amount of water per surface area and time unit that penetrates the soils. The diameter of the inner ring should be approximately fifty (50) percent to seventy (70) percent of the diameter of the outer ring, with a minimum inner ring size of four (4) inches, preferably much larger. (Bouwer, 1986).

Equipment for Double-Ring Infiltrometer Test:

- \_\_\_ Two concentric cylinder rings six (6) inches or greater in height. Inner ring diameter equal to fifty (50) percent – seventy (70) percent of outer ring diameter (i.e. an eight (8) inch ring and a twelve (12) inch ring). Material typically available at a hardware store may be acceptable.
- \_\_\_ Water supply.
- \_\_\_ Stopwatch or timer.
- \_\_\_ Ruler or metal measuring tape.
- \_\_\_ Flat wooden board for driving cylinders uniformly into soil.
- \_\_\_ Rubber mallet.
- \_\_\_ Log sheets for recording data.

Procedure for Double-Ring Infiltrometer Test:

- \_\_\_ Prepare level testing area.
- \_\_\_ Place outer ring in place; place flat board on ring and drive ring into soil to a minimum depth of two (2) inches.
- \_\_\_ Place inner ring in center of outer ring; place flat board on ring and drive ring into soil a minimum of two (2) inches. The bottom rim of both rings should be at the same level.
- \_\_\_ The test area should be presoaked immediately prior to testing. Fill both rings with water to water level indicator mark or rim at thirty (30) minute intervals for one (1) hour. The minimum water depth should be four (4) inches. The drop in water level during the last thirty (30) minutes of the presoaking period should be applied to the following standard to determine the time interval between readings.
  - If water level drop is two (2) inches or more, use ten (10) minute measurement intervals.

- If water level drop is less than two (2) inches, use thirty (30) minute measurement intervals.

\_\_\_ Obtain a reading of the drop in water level in the center ring at appropriate time intervals. After each reading, refill both rings to water level indicator mark or rim. Measurement to the water level in the center ring shall be made from a fixed reference point and shall continue at the interval determined until a minimum of eight readings are completed or until a stabilized rate of drop is obtained, whichever occurs first. A stabilized rate of drop means a difference of one quarter ( $\frac{1}{4}$ ) inch or less of drop between the highest and lowest readings of four consecutive readings.

\_\_\_ The drop that occurs in the center ring during the final period or the average stabilized rate, expressed as inches per hour, shall represent the infiltration rate for that test location.

**b. Methodology for Percolation Test**

Equipment for Percolation Test:

- \_\_\_ Post hole digger or auger.
- \_\_\_ Water supply.
- \_\_\_ Stopwatch or timer.
- \_\_\_ Ruler of metal measuring tape.
- \_\_\_ Log sheets for recording data.
- \_\_\_ Knife blade or sharp pointed instrument (for soil scarification).
- \_\_\_ Course sand or fine gravel.
- \_\_\_ Object for fixed reference point during measurement (nail, toothpick, etc.).

Procedure for Percolation Test

This percolation test methodology is based largely on the Pennsylvania Department of Environmental Protection (PADEP) criteria for onsite sewage investigation of soils (as described in Chapter 73 of the Pennsylvania Code). This must include the twenty four (24) hour presoak procedure between June 1 and December 31. The presoak is done primarily to simulate saturated conditions in the environment (generally Spring) and to minimize the influence of unsaturated flow.

Prepare level testing area.

- \_\_\_ Prepare hole having a uniform diameter of six (6) to ten (10) inches and depth of eight (8) to twelve (12) inches. The bottom and sides of the hole should be scarified with a knife blade or sharp pointed instrument to completely remove any smeared soil surfaces and to provide a natural soil interface into which water may percolate. Loose material should be removed from the hole.

- (Optional) two (2) inches of coarse sand or fine gravel may be placed in the bottom of the hole to protect the soil from scouring and clogging of the pores.
- Test holes should be presoaked immediately prior to testing. Water should be placed in the hole to a minimum depth of six (6) inches over the bottom and readjusted every thirty (30) minutes to one (1) hour.
- The drop in the water level during the last thirty (30) minutes of the final presoaking period should be applied to the following standard to determine the time interval between readings for each percolation hole:
  - If water remains in the hole, the interval for readings during the percolation test should be thirty (30) minutes.
  - If no water remains in the hole, the interval for readings during the percolation test may be reduced to ten (10) minutes.
- After the final presoaking period, water in the hole should again be adjusted to a minimum depth of six (6) inches and readjusted when necessary after each reading. A nail or marker should be placed at a fixed reference point to indicate the water refill level. The water level depth and hole diameter should be recorded.
- Measurement to the water level in the individual percolation holes should be made from a fixed reference point and should continue at the interval determined from the previous step for each individual percolation hole until a minimum of eight readings are completed or until a stabilized rate of drop means a difference of one quarter (¼) inch or less of drop between the highest and lowest readings of four consecutive readings.
- The drop that occurs in the percolation hole during the final period, expressed as inches per hour, shall represent the percolation rate for that test location.
- The average measured rate must be adjusted to account for the discharge of water from both the sides and bottom of the hole to develop a representative infiltration rate. The average/final percolation rate should be adjusted for each percolation test according to the following formula:

Infiltration Rate = (Percolation Rate) / (Reduction Factor)

Where the Reduction Factor is given\*\*:

$$R_f = \frac{2d_1 - \Delta d + 1}{DIA}$$

With:  $d_1$  = Initial Water Depth (in.)  
 $\Delta d$  = Average/Final Water Level Drop (in.)  
 $DIA$  = Diameter of the Percolation Hole (in.)

The Percolation Rate is simply divided by the Reduction Factor as calculated above or shown in the table below to yield the representative Infiltration Rate. In most cases, the Reduction Factor varies from about two (2) to four (4) depending on the percolation hole dimensions and water level drop – wider and shallower tests have lower Reduction Factors because proportionately less water exfiltrates through the

sides. For design purposes additional safety factors are employed (see Protocol 2, Infiltration Systems Design and Construction Guidelines).

*\*\* The area Reduction Factor accounts for the exfiltration occurring through the sides of percolation hole. It assumes that the percolation rate is affected by the depth of water in the hole and that the percolating surface of the hole is in uniform soil. If there are significant problems with either of these assumptions then other adjustments may be necessary.*