Attachment 1: Guidelines for Subsurface Investigation and Infiltration Testing

1.0 Introduction

The guidelines for subsurface investigation and infiltration testing include: evaluation criteria, evaluation process, and soil infiltration testing protocols to follow when designing infiltration Best Management Practices (BMPs). Infiltration BMPs are stormwater management practices aimed at infiltrating some fraction of stormwater runoff from developed surfaces into the soil horizon, thereby attempting to replicate the natural hydrologic regime.

Infiltration testing should be performed at the location of proposed infiltration BMPs per the guidelines provided in this attachment. Table 1.1 summarizes the infiltration BMP siting requirements for evaluating suitability. Suitable infiltration BMP sites shall meet or exceed the evaluation criteria presented in Table 1.1

Table 1.1: Evaluation Criteria

Depth to bedrock	> 4 feet from invert of infiltration BMP to bedrock
Depth to water table	> 4 feet from invert of infiltration BMP to water table
Infiltration rate	> 0.5 in/hr (infiltration rate of native soil at invert of infiltration BMP)
Hotspots	No infiltration BMPs allowed at Hotspots (See Section 2.0)

Infiltration BMPs may not be suited for every site. For example, sites with soil and groundwater contamination are not suited for infiltration BMPs. More examples of hotspots where infiltration BMPs are not suited are provided in Section 2.0 of this document.

If a site is suitable for infiltration BMPs, collecting reliable in situ infiltration rates is critical for design. Section 3.0 provides accepted methodology to use when collecting infiltration rates for a site and reporting requirements.

Safety
As with all field work and testing, attention to all applicable Occupational Safety and Health Administration (OSHA) regulations and local guidelines related to earthwork and excavation is required. In accordance with Indiana Code (IC) 8-1-26, adequate notification before digging and excavation is required through Indiana 811 (indiana811.org or call 811). Excavations should never be left unsecured and unmarked, and all applicable authorities should be notified prior to any work.

2.0 Hotspot Investigation Procedures

Hotspots are locations with potentially contaminated soils where infiltration of stormwater through said soils could negatively impact groundwater and downstream surface water bodies. This policy is intended to encourage infiltration on most sites while avoiding potential contamination of groundwater and surface water caused by infiltration on sites with contaminated soils. Infiltration BMPs are ***not*** allowed at hotspots. A hotspot investigation should be completed for any proposed infiltration BMP using the following procedure:

Step 1: Determine the prior land use at the site to be developed, and review any data on soil or groundwater quality.

- For larger development sites, a formal Phase I site assessment is often required by the lender in order to determine if any environmental hazard exists on the site. A determination of prior land use is part of this assessment.

- On sites where a formal Phase I is not conducted, methods to determine prior land use may include a title search, aerial photographs, soil surveys, topographic maps, city and state regulatory databases, and a review of state and local records.

Step 2: Determine the potential for contamination based on available data and prior land use. The following land uses are considered to have a potential for contaminated soil which may adversely affect the quality of groundwater discharging to surface water. Infiltration is prohibited on these sites unless the applicant can demonstrate that there is no potential for contaminant migration as a result of infiltration.

- Sites designated as CERCLA (Superfund) sites
- Auto recycling facilities and junk yards
- Commercial laundry and dry cleaning
- Commercial nurseries
- Vehicle fueling stations, service and maintenance areas
- Toxic chemical manufacturing and storage
- Petroleum storage and refining
- Public works storage areas
- Airports and deicing facilities, railroads and rail yards, marinas and ports
- Heavy manufacturing and power generation
- Metal production, plating, and engraving operations

- Landfills and hazardous waste material disposal

- Sites on subsurface material such as fly ash known to contain mobile heavy metals and toxins

Step 3: For sites that do not qualify as hotspots, proceed with design of infiltration BMP facilities. For sites that qualify as hotspots, proceed with design of water quality BMPs that do not include infiltration.

3.0 Subsurface Investigation and Soil Infiltration Testing

Subsurface investigation and soil infiltration testing are completed to determine the design infiltration rate and ensure adequate distance between bedrock, the water table, and the bottom elevation of the infiltration BMP. This section provides four main steps for soil infiltration testing and reporting: Background Evaluation, Soil Characterization Testing, Infiltration Testing for Acquiring Design Infiltration Rate, and Reporting of Results.

It is recommended that soil evaluation and investigation be conducted following development of a concept plan or early in the development of a preliminary plan. Soil evaluation and investigation may be conducted by soil scientists, local health department sanitarians, design engineers, professional geologists, and other qualified professionals and technicians. The storm water designer is *strongly* encouraged to directly observe the testing process to obtain a first-hand understanding of site conditions.

Step 1: Background Evaluation

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

- Existing mapped soils and USDA Hydrologic Soil Group classifications.
- Existing geology, including depth to bedrock, or other features of note.
- Existing hydrology (topography, slope, drainage patterns, streams, and watershed boundaries).
- Existing and past land use conditions.
- Other natural or man-made features or conditions that may impact design, such as existing nearby structures (buildings, walls), abandoned wells, etc.
- A concept design plan or preliminary layout plan for development including:
    - Preliminary grading plan and areas of cut and fill,
    - Proposed location of development (specifically, location of infiltration BMPs),
    - Location of all former, existing, and proposed onsite wastewater systems, water supply sources and wells,
    - Location of other features of note such as existing utilities and rights-of-way.

The approximate location of potential infiltration BMPs should be on the proposed development plan and serve as the basis for the location and number of tests to be performed onsite.

Step 2: Soil Characterization Testing

Once locations of potential infiltration BMPs have been identified, soil characterization testing should be conducted to provide a visual assessment of the soil profile and to identify the presence of limiting layers such as groundwater, bedrock, or impermeable soils.

Acceptable soil characterization testing methods include Exploratory Test Pits and Soil Borings. Test pits and soil boring should be located at the proposed infiltration area. Additionally, test pit and soil boring depths should extend a minimum of 4 feet below the bottom of the proposed infiltration area.

Table 3.1 provides guidelines for the quantity of test pits and soil borings. The recommendations in Table 3.1 are guidelines. Additional tests should be conducted if local conditions indicate significant variability in soil types, geology, water table levels, depth and type of bedrock, topography, etc. Similarly, uniform site conditions may indicate that fewer test pits are required. Excessive testing and disturbance of the site prior to construction is not recommended.

Table 3.1: Soil Characterization Testing Quantity Guidelines

Area of Infiltration BMP (ft^2)	Number of Test Pits or Soil Borings
< 1,000	2
1,000 – 10,000	4
> 10,000 ft^2	4 + 1 pit or boring for every additional 5,000 ft^2

After soil characterization testing has been completed, test pit and soil boring stakes should be left in the field to identify the number and locations of tests. The following methodologies should be used when collecting soil information from test pits and soil borings:

Test Pits

A test pit allows visual observation of the soil horizons and overall soil conditions both horizontally and vertically in that portion of the site. A test pit consists of a backhoe-excavated trench. The trench should be benched at a depth of 2-3 feet for access and/or infiltration testing. At each test pit, the following conditions are to be noted and described. Depth measurements should be described as depth below the ground surface:

- Soil horizons (upper and lower boundary)
- Soil texture, structure, and color for each horizon
- Color patterns (mottling) and observed depth
- 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

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

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 90 inches below existing grade, deeper excavation of the test pit will be required. The designer is cautioned regarding the proposal of systems that are significantly deeper than the existing topography, as the suitability for infiltration is likely to decrease. The design engineer is encouraged to consider reducing grading and earthwork as needed to reduce site disturbance and provide greater opportunity for storm water management.

Soil Borings

Soil boring are collected using a hollow-stem auger drilling method. The auger acts as a casing for the borehole, and the center of the auger is hollow to allow for soil sampling. Boring logs may be used as a guide during preliminary evaluation of the feasibility of infiltration BMPs. The logs cannot be used in lieu of post-construction testing or as an infiltration test to establish a design infiltration rate.

Drilling and sampling procedures for soil borings shall follow ASTM D6151-08: Standard Practice for Using Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling, and should include a minimum four-inch inner tube diameter. Standard Penetration Tests (SPT) shall be in accordance with ASTM D1586: Standard Test Method for SPT and Split-Barrel Sampling of Soils. Blow count data should be collected from the soil samples. Soil borings should extend to a depth adequate to show separation between the bottom of the infiltration BMP and the seasonal high groundwater level. The boring depth will vary, based on BMP depth.

Submittals for boring logs should include an associated soil classification consistent with ASTM D2488-17E1: Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). The following information should also be included in a boring log submittal:

- Soil moisture conditions
- Depth and description of undocumented or engineered fill
- Soil color and mottling conditions
- Soil stiffness or density
- Approximate depth of contact between soil types
- Occurrence of saturated soil, impermeable layers/lenses, groundwater, bedrock, or disturbed soil

Boring logs may be used to characterize the soils for a proposed facility as long as the log follows ASTM D2488-17E1, is performed by a qualified professional (Professional Engineer, Registered Geologist, or Certified Engineering Geologist), and demonstrates the potential for infiltration. Logs from outside the immediate vicinity of the proposed facility may be used if the qualified professional can determine that the soil strata are consistent between the proposed facility and the borehole.

Step 3. Infiltration Tests for Acquiring Design Infiltration Rate

A variety of field tests exists for determining the infiltration capacity of a soil. Laboratory tests are not recommended, as a homogeneous laboratory sample does not represent field conditions. Infiltration tests should be conducted in the field. Infiltration tests should not be conducted in the rain, within 24 hours of significant rainfall events (> 0.5 inches), or when the temperature is below freezing. Testing should be conducted in the proposed area of infiltration, and testing may be conducted within an open test pit or standard soil boring. The testing depth should be a minimum of 4 feet below the bottom of the proposed infiltration area. Based on observed field conditions, the designer may elect to modify the proposed bottom elevation of a BMP. Personnel conducting infiltration tests should be prepared to adjust test locations and depths depending on observed conditions. Table 3.2 provides guidelines for the number of infiltration tests based on the proposed infiltration area.

Table 3.2: Infiltration Testing Quantity Guidelines

Area of Infiltration BMP (ft^2)	Number of Infiltration Tests
< 1,000	2
1,000 – 10,000	4
> 10,000 ft^2	4 + 1 test for every additional 5,000 ft^2

Methodologies discussed in this protocol include:

- Double-ring infiltrometer tests
- Percolation tests

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 from the inner ring. 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.

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 Storm water Manual*, Appendix D.1, using five-inch diameter casing.
- ASTM 2003 Volume 4.08, Soil and Rock (I): Designation D 3385-03, 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).

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 the amount of water per surface area and time unit which penetrates the soils. The diameter of the inner ring should be approximately 50-70 percent of the diameter of the outer ring, with a minimum inner ring size of four inches. Double-ring infiltrometer testing equipment designed specifically for that purpose may be purchased. However, field testing for storm water BMP design may also be conducted with readily available materials.

Equipment for double-ring infiltrometer test include: Two concentric cylinder rings six inches or greater in height. Inner ring diameter equal to 50-70 percent of outer ring diameter (i.e., an eight-inch ring and a 12-inch ring). Additional materials typically available at a hardware store may be acceptable, such as:

- 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

1. Prepare level testing area.

2. Place outer ring in place; place flat board on ring and drive ring into soil to a minimum depth of two inches.

3. Place inner ring in center of outer ring; place flat board on ring and drive ring into soil a minimum of two inches. The bottom rim of both rings should be at the same level.

4. The test area should be presoaked immediately prior to testing. Fill both rings with water to water level indicator mark or rim at 30-minute intervals for one hour. The minimum water depth should be four inches. The drop in the water level during the last 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 inches or more, use 10-minute measurement intervals.

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

5. 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 should be made from a fixed reference point and should 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 ¼ inch or less of drop between the highest and lowest readings of four consecutive readings.

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

Methodology for percolation test

Equipment for conducting a percolation test includes:

- Post hole digger or auger
- Water supply
- Stopwatch or timer
- Ruler or 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 criteria for onsite sewage investigation of soils. A 24-hour pre-soak is generally not required as infiltration systems, unlike wastewater systems, will not be continuously saturated.

1. Prepare level testing area.

2. Prepare hole having a uniform diameter of 6-10 inches and a depth of 8-12 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.

3. (Optional) Two 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.

4. Test holes should be presoaked immediately prior to testing. Water should be placed in the hole to a minimum depth of six inches over the bottom and readjusted every 30 minutes for one hour.

5. The drop in the water level during the last 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 30 minutes.

    - If no water remains in the hole, the interval for readings during the percolation test may be reduced to 10 minutes.

6. After the final presoaking period, water in the hole should again be adjusted to a minimum depth of six 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.

7. 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 is obtained, whichever occurs first. A stabilized rate of drop means a difference of ¼ inch or less of drop between the highest and lowest readings of four consecutive readings.

8. The drop that occurs in the percolation hole during the final period, expressed as inches per hour, should represent the percolation rate for that test location.

9. The average measured rate must be adjusted to account for the discharge of water from both the sides and bottom of the hole and to develop a representative infiltration rate. The average/ final percolation rate should be adjusted for each percolation test according to the Equation 1.

Equation 1:

$$Infiltration\ Rate\ = \frac{Percolation\ Rate}{Reduction\ Factor}$$

Where the Reduction Factor[1] is given by Equation 2.

Equation 2:

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

With:
d_1 = Initial Water Depth (in.)
Δd = 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 Table 3.3 to yield the representative infiltration rate. In most cases, the reduction factor varies from about two to four 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.

[1] 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.

Table 3.3 Sample Percolation Rate Adjustments

Perc. Hole Diameter (in.)	Initial Water Depth, D_1 (in.)	Ave./Final Water Level Drop, Δd (in.)	Reduction Factor, R_f
6	6	0.1	3
		0.5	2.9
		2.5	2.6
	8	0.1	3.7
		0.5	3.6
		2.5	3.3
	10	0.1	4.3
		0.5	4.3
		2.5	3.9
8	6	0.1	2.5
		0.5	2.4
		2.5	2.2
	8	0.1	3
		0.5	2.9
		2.5	2.7
	10	0.1	3.5
		0.5	3.4
		2.5	3.2
10	6	0.1	2.2
		0.5	2.2
		2.5	2
	8	0.1	2.6
		0.5	2.6
		2.5	2.4
	10	0.1	3
		0.5	3
		2.5	2.8

Additional Potential Testing – Bulk Density

Bulk density tests measure the level of compaction of a soil, which is an indicator of a soil's ability to absorb rainfall. Developed and urbanized sites often have very high bulk densities and, therefore, possess limited ability to absorb rainfall (and have high rates of storm water runoff). Vegetative and soil improvement programs can lower the soil bulk density and improve the site's ability to absorb rainfall and reduce runoff.

Applicability of Testing Results

Infiltration test results acquired using the above methods are used to determine if infiltration BMPs are suitable at a site, as well as to obtain the required data for infiltration BMP design. Even with appropriate infiltration rates, sites may be unsuitable for infiltration BMPs due to proposed grade changes (excessive cut or fill), lack of suitable areas, size constraints, or hotspots. With lower infiltration rates, the use of underdrains, treatment trains, or overflows may make the practice more suitable. Recommended infiltration rates and drain down times for infiltration practices are included in the cited attachment for each practice per Table 3.4.

Table 3.4 Drawdown Time

Infiltration BMP	Maximum Drawdown Time	
Permeable Pavement	72 hours	
Bioinfiltration, Bioretention, Rain Garden	48 hours	
Swale	72 hours	

Step 4. Soil Infiltration Report

At the conclusion of soil infiltration testing a Soil Infiltration Report should be prepared and filed with the site design documents. The Soil Infiltration Report should contain the following information:

1. Scope of investigation
2. General description of the proposed development for which the exploration has been conducted
3. Geologic conditions of the site
4. Drainage facilities at the site
5. Details of boring
6. Description of subsoil conditions as determined from the soil and rock samples collected
7. Groundwater table as observed from the boreholes
8. Details on recommendations and alternatives
9. Any anticipated construction problems
10. Limitations of the investigation

The following supporting exhibits should also be included the Soil Infiltration Report:

1. Site location map
2. Location of boring and/or test pits with respect to the proposed development
3. Boring logs
4. Laboratory test results
5. Other relevant presentations and results

References

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