Infiltration and Soil Testing Introduction

The goals of Runoff Reduction and compliance with the Watershed Protection Elements (Chapter 4-1) and the performance standards of Site and Neighborhood Design on new and re-development are based on having a practical understanding of the soil conditions and their hydrologic response characteristics. This is especially important in the initial layout and design of the site development infrastructure: strategically locating impervious cover over soils with low permeability (Hydrologic Soil Groups C and D), and directing runoff to soils that are highly permeability (Hydrologic Soil Groups A and B).

Accurately identifying the Hydrologic Soil Group (HSG) of the existing soils is also an important first design step in computing the design Treatment Volume (Tv) and appropriate runoff reduction credit. More importantly, drainage area runoff computations using the Natural Resources Conservation Service (NRCS) methodology require knowledge of a soil's HSG, particularly for soils with pervious land covers.

NOTE: An interactive web-based soil rating system for rating the suitability of West Virginia soils for stormwater management practices is under development. Specific soil criteria are used to develop soil suitability ratings, limitations, and recommendations for the applicability of specific stormwater BMPs. More information on this assessment tool will be made available by DEP.

This Soil Infiltration section is a reproduction from the West Virginia Stormwater Management and Design Guidance Manual

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1. Site Evaluation – Initial Screening

The initial screening of the on-site soils should be conducted in conjunction with the Natural Resources Inventory (Specification 4.1.2). This exercise should identify basic soil characteristics related to stormwater management, such as the Hydrologic Soil Groups (HSG), as well as other features relevant to construction activities (e.g. erosion and sediment control). Also, the initial screening should identify where more detailed soil investigation and field determinations may be needed to refine the limits of the different HSGs as defined in the soil survey, or where field conditions indicate different characteristics than those indicated in the survey.

The initial screening should also include the identification of locations deemed suitable for infiltration BMPs and therefore further detailed geotechnical investigations. In general, designers should evaluate the potential for multiple small infiltration practices rather than relying on fewer large scale infiltration practices. Experience in other jurisdictions indicates that larger infiltration practices with correspondingly large contributing drainage areas experience maintenance problems due to excessive hydraulic loading (CWP 2009). Multiple smaller infiltration practices will also be less likely to have groundwater mounding problems.

Therefore, the initial screening should be broad in terms of soil types across the site, yet also detailed enough to advise the efficient implementation of more detailed soils and subsurface investigation.

> NOTE: Designers must be aware of the proposed earthwork for the final development layout when conducting the Initial Screening. Areas of cut and/or fill must be carefully evaluated for structural stability in addition to any precautions with regard to stormwater management designs. Infiltration or infiltration sumps located in the vicinity of fill has the potential to compromise the stability of the fill section by creating a slipplane.
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> If the designer is not be aware of the final grading plan when developing a stormwater concept plan, he/she must coordinate the stormwater BMP type and placement with the site designer to ensure that the final locations are investigated and a licensed or otherwise qualified professional (as described in Section 6.a. of this Appendix) has conducted a geotechnical exploration and provided design recommendations. These recommendations must be included in the final geotechnical report as well as the stormwater management design report.
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> NOTE: This guidance may not be applicable in cases where soils have been identified as having been reconstructed, such as old mining areas. Subsurface drainage and other soil suitability issues of abandoned or reclaimed minimg areas are beyond the scope of this guidance.

2. Site Evaluation – Soil Characterization and Hydrologic Soil Groups

In accordance with NRCS recommendations, a soil's HSG is typically determined through information available in the NRCS Soil Survey. Detailed information can be found in local USDA NRCS Soil Surveys or online at the USDA NRCS Data Mart (http://soildatamart.nrcs.usda.gov). However, at certain locations, the Soil Survey does not have sufficient information to determine the HSG, or it has been mapped as Urban Land with an assumed default HSG D. It is also possible that direct soil observations or tests may indicate that a soil's HSG is different than that which is provided by the Soil Surveys due to mapping errors or the soil having been altered through cuts, fills or other disturbances.

In all cases, the designer should evaluate the existing soils to ensure a proper HSG designation for calculating the Runoff Reduction Treatment Volume, as well as any other construction related soil suitability limitations.

Soils are grouped into Hydrologic Soils Groups A, B, C, or D based on similarities in certain characteristics:

soil texture and structure;

- depth to a restrictive layer: (i.e. soil morphological characteristics which restrict the vertical movement of water including but not limited to abrupt textural boundaries, fragipan, bedrock, dense or cemented soils);

- depth to water table;
- hydraulic conductivity or transmission rate of water; and
- degree of swelling when saturated

The definitions of common terms used throughout the specification are provided for clarity:

Soil infiltration – the rate at which stormwater enters the soil. Infiltration is influenced by soil structure, compaction, organic matter, moisture content, and other physical characteristics at the soil surface. The design infiltration rate is usually expressed as a constant value.

Soil permeability – the rate at which stormwater flows through the soil.

NOTE: Infiltration and Permeability are used interchangeably in many reference materials.

The infiltration and permeability of a given soil can be related to the hydraulic conductivity of the soil (K). The rate at which water enters the soil (infiltration), under optimal conditions, starts very fast and gradually declines and eventually approaches a constant rate. This constant rate of infiltration is sometimes called the soil's permeability, but is technically defined as the saturated hydraulic conductivity (Ksat). In almost all cases, reference to an infiltration rate or permeability implies this long-term constant rate (permeability, Ks or Ksat). (Jarrett, 2008).

The property that is most limiting to water movement generally determines the soil's hydrologic group. (USDA NRCS, May 2007) For example, in terms of soil texture, Group C soil includes silt loam and sandy clay loam

and is typically between 20 percent and 40 percent clay and less than 50 percent sand. There are some overlaps where the texture classes may include a range of sand-silt-clay fractions in one HSG and the same texture name with a slightly different fraction in a different HSG. For example, soils having clay, silty clay, or sandy clay texture (typically grouped in HSG D) may be placed in Group C if they are well aggregated, of low bulk

density, or contain greater than 35 percent rock fragments. Equally important are the defining physical characteristics of the group: the depth to a restrictive layer or water table, and saturated hydraulic conductivity. For Group C, the depth to any water impermeable layer is greater than 20 inches, and the depth to the water table is greater than 24 inches. Soils that are deeper than 40 inches to a restriction or water table are in Group C if the saturated hydraulic conductivity of all soil layers within 40 inches of the surface is less than 0.57 inches per hour (but exceeds 0.06 inches per hour). The saturated hydraulic conductivity in the least transmissive layer between the surface and 20 inches is between 0.14 in/hr and 1.42 in/hr. In very general terms, water transmission through C soils is somewhat restricted, and they have moderately high runoff potential when thoroughly wet. A general definition of the HSG is provided:

Group A. Soils with low runoff potential. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep well drained to excessively well-drained sands or gravels and have a high rate of water transmission.

Group B. Soils having moderate infiltration rates even when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well drained to well drained soils with moderately fine to moderately coarse textures and have a moderate rate of water transmission .

Group C. Soils having slow infiltration rates even when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures and have a slow rate of water transmission .

Group D. Soils with high runoff potential. Soils having very slow infiltration rates even when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material and have

a very low rate of water transmission.

NOTE: Readers are encouraged to refer to National Engineering Handbook Chapter 7: Hydrologic Soil Groups, and the USDA Soil Survey Manual, Chapter 3 for detailed guidance on the application of soil classification criteria for determining the hydrologic group of a particular soil based on the characteristics observed and recorded from the soil profile pits and soil borings: soil texture, bulk density, depth to water table (or other restrictive layer), and if available, the saturated hydraulic conductivity.

"Restrictions" in the soil profile are defined in the 1996 National Soil Survey Handbook and include, but are not limited to the presence of bedrock, dense material, fragipans, and ortsteins. The seasonally high water table is based on either observed saturation or redoxomorphic features. The presence and depth of these restrictions must be included in the soil logs.

Table B.1 provides guidelines for the number of soil test pits and soil borings for identifying and classifying soils on a development site (Section 3 below provides additional information on the soil borings and profile pits). The lead investigator should evaluate the available soil survey information and compare it with site visit observations to determine if more soil exploration than that noted below will be required for accurate classification.

Table B.1 Soil Exploration Required for Hydrological Soil Group Classification

Mapping unit or DA size		
< 0.5 ac	**> 0.5 ac; < 2.0 ac**	**> 2 ac**
1 Soil Profile Pit 1 Soil Boring	1 Soil Profile Pit 4 Soil Borings	1 additional Soil Profile Pit[1] 2 additional Soil Borings[1]

[1] For each additional 2 acres

3. Site Evaluation: Soil Testing for Infiltration BMPs

Where infiltration of runoff into the existing soil strata is part of the selected BMP runoff reduction strategy, the designer must determine the actual soil permeability (or saturated hydraulic conductivity) through field tests. The failure of stormwater infiltration devices is often attributed to an inaccurate estimation of the design infiltration rate and/or depth to the seasonal high water table or other limiting layer.

There are also numerous examples of infiltration BMP failures attributed to a lack of sediment control or other protections during construction, or inadequate runoff pretreatment and long term maintenance. However, those deficiencies are addressed through better design, construction, and operation and maintenance guidance. The purpose of this guidance is to provide clear expectations for the number and type of soil tests required in order to ensure that the individual infiltration practice is appropriate for specific site location.

The goal of the soil tests are to establish detailed information on groundwater conditions and physical characteristics of the soil to determine the suitability of the soil for a stormwater infiltration BMP. Soil testing will include soil test pits, soil borings, and soil infiltration tests.

A soil test pit is an excavation made for the purpose of exposing and evaluating the soil profile, and for conducting a soil permeability test at the appropriate depth. Data recorded in each reference test pit is to be compared to the soil profile described in the adjacent soil boring(s) to confirm consistence between the test pit and the boring. Where soil and/or groundwater properties vary significantly between soil boring and profile pit explorations, additional soil profile pits should be conducted as necessary to resolve such differences and accurately characterize the soils in the area of interest.

In areas where a soil profile pit would substantially disturb the existing area and create an undesirable condition or where significant environmental disturbance will occur in an area that is not intended for future development, two soil borings may be conducted in the place of a required soil profile pit with a soil profile pit located at the closest available location representative of the soil boring locations. If the location of the soil appendix B A B.7 pp endix B: Infi ltration and Soil Testing

West Virginia Stormwater Management & Design Guidance Manual Appendix B : Infiltration and Soil Testing, November 2012 Page Appendix B-7 profile pit is not representative of the soil borings taken, it is the responsibility of the design engineer to demonstrate the consistency of soil profile pit data to the soil characteristics at the location of the soil borings.

Number and location of soil explorations:

A Soil profile pit and soil borings are only required in the areas of the BMP being utilized for infiltration. (Additional soils exploration may be necessary if the designer needs to verify the site HSGs for runoff and Tv calculations.) Where only a portion of the BMP's bottom is being utilized for infiltration, the infiltration area is applicable only to that portion of the BMP. Placement of soil test pit shall be such that it provides adequate characterization of the infiltration area.

- 1 soil profile pit shall be excavated within the infiltration area of any proposed infiltration BMP up to 2,500 ft^2 in area;
- 2 soil profile pits and 2 soil borings for BMP infiltration areas between 2,500 ft^2 and 5,000 ft^2 in area;
- 2 soil profile pits and 3 soil borings for BMP infiltration areas larger than 5,000 ft^2 in area;
- 1 additional soil profile pits and 2 additional soil borings for each increase in infiltration surface area of 5,000 ft^2.

The total number of required soil profile pits shall be placed generally equidistant from each other so as to provide adequate characterization of the infiltration area.

For linear infiltration BMPs (infiltration area length to width ratio of 4 to 1):

- 1 soil profile pit shall be excavated in a representative 100 ft section of the infiltration area;
- 1 additional soil profile pit and 1 soil boring within each additional 200 ft section of infiltration area.

For sites with multiple infiltration BMPs each with surface areas less than 500 square feet, a minimum of one (1) soil profile pit is required for the site and one soil boring per infiltration BMP. In doing so, the test pit must be properly located within the overall site to adequately depict site soil conditions. Where soil and/or groundwater properties vary significantly between soil explorations, additional soil profile pits shall be conducted as necessary to resolve such differences and accurately characterize the soils. For infiltration practices associated with single family residential development, only one soil boring is required per lot.

> NOTE: If there are notable inconsistencies between the soil profiles and the profile pit within the area of any one or multiple infiltration locations, it is the responsibility of the design engineer to ensure a sufficient number of soil explorations are conducted to ensure an accurate representation of the soil conditions.

Depth of Test Pits and Soil Borings

In order to evaluate the infiltrative capacity of the soils at the location of the proposed infiltration BMP, soil borings and test pits should be to a depth of 3 feet below the bottom of the BMP, or a depth of two times the maximum potential water depth in the BMP below the proposed surface of the BMP, whichever is greater.

Where soil replacement below the bottom of the BMP is proposed, the test pit and/or soil boring should extend below the depth of soil replacement to a depth equal to two (2) times the maximum potential water depth within the basin or 3 feet below the bottom elevation of the soil replacement, whichever is greater.

Documentation of the soil test pits and soil borings

The location of the soil explorations must be shown on a legible site plan/map that is:

- Is drawn to scale or fully dimensional.
- Illustrates the location of the infiltration devices.
- Shows the location of all pits and borings.
- Shows distance from infiltration devices to wetlands, or other sensitive features.

NOTE: Contractors must contact the West Virginia Miss Utility One-Call System (811) prior to the excavation of test pits or soil borings in accordance with Section XIV: West Virginia Chapter 24-C.

Soil Logs

A soil log shall be prepared for each soil profile pit and soil boring in accordance with ASTM D 1452 Practice for Soil Investigation and Sampling Auger Borings & ASTM D 1586 - Test Method for Penetration Test and Split-Barrel Sampling of Soils. The soil boring log shall, at a minimum, provide the following:

a. elevation of the existing ground surface and elevations of permeability test locations;

b. the depth and thickness of each soil horizon and the depth to the substratum; T

c. the dominant matrix or background and mottle colors, abundance, size, and contrast using the Munse system of classification for hue, value and chroma;

d. the appropriate textural class as shown on the USDA textural triangle;

e. the volume percentage of coarse fragments larger than two (2) millimeters in diameter;

f. soil structure, particle sizes, and shape;

g. the soil moisture condition, using standard USDA classification terminology;

h. the presence of any soil horizon, substratum or other feature that exhibits an in place permeability rate less than one (1) inch per hour;

i. the depth and occurrence of soil restrictions including, but not limited to, abrupt textural boundaries likely to restrict the movement of water, fragipans, dense materials, bedrock, and ortstein;

j. the depth to the seasonally high ground water level, either perched or regional;

k. any observed seepage or saturation.

The results and locations of all soil profile pits, borings and soil permeability tests, both passing and failing, should be included in the Stormwater Management Report submitted to the appropriate review agency. All soil evaluations, including test profile pits, soil borings, and permeability tests shall be conducted under the supervision of a licensed Soil Scientist or other licensed professional acceptable to the authority having jurisdiction.

4. Soil Permeability Testing

Soil permeability can be determined by one of two methods:

a. Permeability tests performed at each soil profile pit; or

b. Permeability determined by field verifying the USDA Soil Texture Class and bulk density of the most restrictive layer as recorded in the soil test pits and soil borings, and selecting the corresponding saturated hydraulic conductivity from Table B.1.

Permeability Tests

Permeability tests must be conducted at the most restrictive layer between the bottom elevation of the proposed infiltration BMP and a depth of 3 feet below the bottom, or two times the maximum potential water depth in the BMP, whichever is greater. For example, permeability tests for a bioretention basin that is proposed to be 4 feet in depth with a maximum potential water depth of 4.5 feet should be conducted at the most restrictive layer between a depth of 4 feet and the greater of 7 feet or two times the water depth, or 9 feet, below the surface.

Where stormwater infiltration BMPs are in proximity to fractured bedrock, there should be a minimum of two feet of soil between the bottom of the infiltration BMP and the bedrock. Where the permeability rate of the bedrock is critical to the function of the basin, the design engineer shall demonstrate that appropriate testing methods as discussed in this section are utilized to establish the permeability rates of the infiltration BMP.

The number of permeability tests for fractured bedrock should be no less than the tests required for permeability in the soil. The design permeability rate of 0.5 in/hr can be used for bedrock when the basin drains completely within 12 hours during a basin flood test performed as described in this guidance. To use permeability rates greater than 0.5 in/hr, more detailed testing is required.

The following tests are acceptable for use in determining soil infiltration rates. Other tests may be allowed at the discretion of the local plan approving authority. The Geotechnical Report shall include a detailed description of the test method and published source references:

- Tube Permeameter Method (ASTM D 2434);
- Double-Ring Infiltrometer (ASTM D 3385);
- Basin flooding test for bedrock (refer to Section 5 of this Appendix);
- Percolation Test (64CSR47 - §64-47-6.6.3); or
- other constant head permeability tests that utilize in-situ conditions and accompanied by a recognized published source reference.

USDA Soil Texture Classes

The permeability or saturated hydraulic conductivity of a soil can be measured directly using the tests noted above, or estimated indirectly from the soil texture data collected through the soil profile test pits or soil borings. The following information has been excerpted from Rawls et al. 1998, and provides designers with a conservative estimate of the saturated soil conductivity based on the USDA Soil Texture Classes and bulk density. This may save some time and expense in field testing; however it is admittedly an estimate and may yield a lower or more conservative conductivity and therefore potentially increase the size (or eliminate altogether) any proposed infiltration practices that would otherwise be designed with field verified infiltration tests.

Table B.2 provides the Saturated Hydraulic Conductivity for soils classified by USDA Soil Texture Classes and further divided into two bulk density classes according to whether the bulk density was above or below a given value recommended by NRCS.

The bulk density of a soil has a measureable effect on hydraulic conductivity (Ks) (Rawls et al.,1992). Typically as bulk density increases (or porosity decreases), the Ks decreases. There are some exceptions to this rule, as evidenced by the Ks values for oam and silty clay loam. These values are derived from Rawls et al. 1998, and represent the geometric mean of soil data collected as part of a national data base. The exceptions noted are potentially a result of the variability in the data.

It is important to note that the ultimate long term performance of the infiltration BMP is dependent on a good design that is based on accurate supporting soils data. Designers and developers should consider the long

term performance and the operation and maintenance costs in present dollars when electing to forgo the more accurate field infiltration tests.

5. Basin Flooding Test

A Basin flooding test can be utilized to establish the permeability rates of bedrock in accordance to the procedures below. The basin flooding test shall not be conducted in rock strata which have been blasted with explosives.

a. Equipment Requirements

The following equipment is required for performing a Basin flooding test:

- Excavating equipment capable of producing a test basin as prescribed in b below;
- A water supply (minimum of 375 gallons per basin filling); and
- A means for accurately measuring the water level within the basin as required in ‘c’ below.

b. Test Basin Preparation

The test basin shall be prepared in accordance with the following:

- A test basin meeting the following requirements shall be excavated within or immediately adjacent to the area of concern.
- The bottom area of the basin shall be a minimum of 50 square feet.
- The bottom of the basin should be made as level as possible so that high areas of rock do not project above the water level when the basin is flooded as prescribed in ‘c’ below.
- If groundwater is observed within the test basin, the basin flooding test shall not be used.

Table B.2. Saturated Hydraulic Conductivity Classified by USDA Soil Texture Classes and Bulk Density (Source: Rawls et al. 1998)			
Soil Group	**Soil Texture[1]**	**Bulk Density(lb/ft3)**	**Design Infiltration Rate without Measurement (in/hr)[2]**
A	Coarse sand, Sand	> 97	7.16
		> 97	3.60
A	Loamy sand	> 97	4.84
		> 97	1.63
B	Sandy loam	> 97	2.20
		> 97	0.50
B	Loam	> 90	0.15
		> 90	0.24
C	Silt loam	> 90	0.57
		> 90	0.13
C	Sandy clay loam	> 97	0.30
		> 97	0.11
D	Clay loam	> 94	0.17
		> 94	0.03
D	Sandy clay		0.04
D	Silty clay		0.07
D	Clay		0.07

[1]For fine sand texture – use loamy sand; for loamy fine sand texture – use sandy loam; for fine sandy loam texture – use loam;

[2] Geometric mean of saturated hydraulic conductivity of all samples taken.

c. Basin Flooding Testing Procedure

The following procedure shall be used to conduct the Basin Flooding test:

- Step One: Fill the test basin with exactly 12 inches of water and record the time. Allow the basin to drain completely. If the time required for the basin to drain completely is greater than 24 hours, the test shall be terminated and the limiting zone in question shall be considered to be a massive rock
- Step Two: If the basin drains completely within 24 hours after the first flooding, immediately refill the basin to a depth of 12 inches and record the time. If the basin drains completely within 24 hours of the second filling, the limiting zone in question shall be considered to be fractured rock substratum. If water remains in the basin after 24 hours the limiting zone in question shall be considered to be a massive rock substratum.

d. Permeability Rate Determination

A design permeability rate shall only be used if the basin drains completely within 12 hours while performing Step Two described in ‘c’ above. The design permeability rate used shall be 0.5 in/hr.

6. Additional Considerations

The following are general considerations that should be included in the development of the infiltration BMP design:

a. Qualifications: Soil Evaluations - Individuals completing the soils evaluation should be either a Soil Scientist licensed by the West Virginia Department of Regulation and Licensing, or be a Full Member in good standing with the West Virginia Association of Professional Soil Scientist (http://www.wvapss.org)

b. Infiltration BMPs should not be constructed until after all upstream areas have been adequately stabilized. If this is not possible, multiple levels of construction erosion and sediment controls should be used to protect the infiltration area and to prevent sediment laden runoff from entering the facility. This includes temporary erosion controls for site grading as well as home building and construction, as well as long term measures that will protect the infiltration area through at least two growing seasons.

c. The approval process requirements for development sites vary across the state and may also vary within a municipality depending on the size of the development (number of lots, square footage of disturbance). The timing of the Natural Resources Inventory and the follow-up field verification in conjunction with preliminary plan, stormwater concept plan, and final design plan may be dictated by the local plan approving process.

It is recommended that the Natural Resources Inventory be completed before the preliminary site design. The follow-up field verification should be completed concurrently with the stormwater concept plan (use the stormwater concept plan to direct the field investigation).