Appendix 1. Soil Investigation Procedures for Stormwater BMPs

Delaware DNREC, Sediment & Stormwater Program
(Adapted from Wisconsin Department of Natural Resources)

SUMMARY OF INFILTRATION TESTING PROCEDURES

This summary has been prepared as "quick reference guide" for procedures to be followed when performing soil infiltration testing required under Article 3.06.2 Post Construction Stormwater BMP Standards & Specifications. Refer to the complete practice standard for more detailed information on additional soil investigation procedures. In order to minimize inconsistencies in the collection and interpretation of field data, the following procedure has been developed. This document should be taken as the minimum requirements for soils investigation for stormwater infiltration BMPs. The soil professional should rely on his or her experience to develop a site investigation plan based on site and design specific requirements. Any significant deviation from this procedure must be discussed with DNREC or the delegated stormwater agency having jurisdiction.

1. Site Investigations to be performed by certified or licensed individuals having the necessary knowledge, skills and training in soil investigation, interpretation and classification. Individuals performing the infiltration testing shall possess a Class A On-Site License issued by DNREC or be licensed in the State of Delaware as a Geotechnical Engineer or Geologist.
2. An initial Screening of readily available data is necessary to determine feasibility of infiltration practices. Screening to include at a minimum:
    a. Site topography
    b. Soil characteristics as defined in the USDA NRCS County Soil Survey
    c. Depth to ground water
    d. Distance to known remediation sites and presence of contaminated groundwater within 500 feet of the site
    e. Historical groundwater level data from the nearest Delaware Geological Survey (DGS) monitoring well or wells.
3. Borings and pits shall be dug to verify soil profile and to determine depth to groundwater and bedrock. Borehole or test pit logs must record:
    a. Name of individual collecting the field data and date
    b. Type of boring or test pit excavation method/ equipment
    c. Air temperature and precipitation, including significant precipitation prior to investigation
    d. Elevation of boring location based on site benchmark

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   e. Visual description of soil profile layers, and depths below grade encountered
   f. Depths of instability such as cave in, sloughing, flowing sands, or obstructions
   g. Depth of seasonal high ground water indicators such as mottling
   h. Depth of encountered free water during and after excavation
4. Borings or Test pits must be advanced to depth of groundwater or at least 3 feet below estimated bottom of proposed infiltration facility.
5. Field Permeability Testing to be done in accordance with ASTM-D5126 "Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone" Single Ring or Double Ring Infiltrometer are preferred test methods, however Borehole Permeameter method is allowable only in cases where test pit excavation depths or site constraints pose safety concerns.
6. Infiltration test log must state:
   a. Name of individual preforming test and date
   b. Type of test method (single/double ring or borehole and whether constant or falling head)
   c. Air temperature and precipitation,
   d. Depth of test below ground surface, and elevation,
   e. Diameters of boring and casing, and depth of casing penetration
   f. Time and depth from reference point for each time increment
7. For both constant and falling head test methods, a saturation period of 1 hour or a drop of 12 inches (approx. 30 cm) is required. The saturation period shall not be used in determining design infiltration rate.
8. After the saturation period, a minimum of two test periods are required or until at least 2 consecutive runs are consistent. Each test period is to be a minimum of one hour or a drop of 12 inches.
9. For falling head test method, each run is to start at the same initial head to normalize the effect of head on the measured drop.
10. A legible boring or test pit location map must be included. The map must be drawn to scale and show relevant site features.
11. The site investigation report must identify the depth of seasonal high water table through visual soil indicators (mottling) and correlation of observed water table to historical groundwater level data from the nearest Delaware Geological Survey monitoring well or wells. The effect on groundwater fluctuation by water features intercepting the groundwater table such as streams and ditches should be considered as well as perched water conditions.
12. The site investigation report must be signed and sealed by the professional responsible for its contents and conclusions.

I. Definition

This standard defines soil investigation procedures to:

1. Perform an initial screening of a *development site*[1] to determine its suitability for potential stormwater Best Management Practices (BMPs).
2. Evaluate each area within a development site that is selected for runoff reduction.
3. Determine suitability of on-site soils to meet any structural needs.
4. Prepare a Soils Investigation Report.

II. Purpose

1. Establish methodologies to characterize the site and screen for exclusions and exemptions under the Delaware Sediment & Stormwater Regulations (DSSR).
2. Establish requirements for siting a *runoff reduction practice*[1] and the selection of design infiltration rates.
3. Establish location of on-site soils used for construction of stormwater BMPs.
4. Define requirements for a site evaluation report that insures appropriate areas are selected for infiltration and an appropriate *design infiltration rate*[1] is used, as well as whether on-site soils are adequate for the construction of proposed stormwater BMPs.

III. Conditions where Practice Applies

This standard is intended for development sites being considered for stormwater management BMPs. Additional site location requirements may be imposed by other stormwater BMP technical standards.

IV. Federal, State and Local Laws

Users of this standard shall be aware of applicable federal, state and local laws, rules, regulations or permit requirements governing infiltration devices. This standard does not contain the text of federal, state or local laws.

V. Criteria

The site evaluation consists of four steps for locating the optimal areas for infiltration, properly sizing infiltration devices, and suitability for construction of stormwater BMPs.

- Step A. Initial Screening.
- Step B. Field Verification of information collected in Step A.
- Step C. Evaluation of specific *Infiltration Areas*[1].

- Step D. Soil and Site Evaluation Reporting.

The steps shall coincide, as much as possible, for when the information is needed to determine the following: 1) the potential for infiltration on the site, 2) the optimal locations for infiltration practices, and 3) the design of the stormwater BMPs. Steps A and B shall be completed as soon as possible in the approval process.

[1] NOTE: Words in the standard that are shown in italics are described in VIII. Definitions. The words are italicized the first time they are used in the text.

Step A. Initial Screening

The initial screening identifies potential locations for infiltration practices. The purpose of the initial screening is to determine if installation is limited by soils, water table or other physical site features, and to determine where field work is needed for Step B. Optimal locations for infiltration are verified in Step B.

Information collected in Step A will be used to explore the potential for multiple infiltration areas versus relying on a regional infiltration practice. Smaller infiltration practices dispersed around a development are usually more sustainable than a single regional facility that is more likely to have maintenance and groundwater mounding problems.

The initial screening shall determine the following:

Note: Useful references for the existing resource maps and information are listed in Considerations VI.I and J.

1. Site topography and slopes greater than 20%.
2. Site soil infiltration capacity characteristics as defined in NRCS County soil surveys.
~~3. *Soil parent material*.~~
4. Regional or local depth to groundwater and bedrock. Use seasonally *high groundwater* information where available.
5. Distance to known remediation sites within 500 feet from the perimeter of the development site.
~~6. Presence of endangered species habitat.~~
~~7.~~6. Presence of flood plains and flood fringes.
~~8.~~7. Location of hydric soils based on the USDA County Soil Survey and wetlands from the DNREC State Wetland Mapping Program (SWMP).
~~9.~~8. Sites where the installation of stormwater infiltration practices is excluded, due to the potential for groundwater contamination.
~~10.~~9. Proximity of water supply wells and on-site wastewater disposal systems.
10. Potential impact to adjacent property.
11. Historical groundwater level data from the nearest Delaware Geological Survey

monitoring well or wells.

Step B. Field Verification of the Initial Screening

A. Field verification is required for areas of the development site considered suitable for infiltration. This includes verification of Step A.1, 2, ~~3,~~ 4, 9, 10 and 11.

B. ~~Sites shall be tested for depth to groundwater, depth to bedrock and *percent fines* information to verify any exemption and exclusion found in Step A.10 and 11.~~ Borings and pits shall be dug to verify soil infiltration capacity characteristics and to determine depth to groundwater and bedrock

C. Soils and geotechnical investigations must consider the following, where applicable based on the proposed Stormwater BMP:

1. Boreholes: Test borings for pond embankments must be located in the footprint of the embankment, spillway excavation and appurtenant structures. Boreholes must extend to sound bedrock or at least to the depth equal to the height of the dam. When the boreholes are extended to bedrock, coring of the bedrock must be performed following ASTM Standard D2113 to assess its quality and characteristics. The borehole logs must record the depths of any problems such as borehole instability (cave in, squeezing hole, flowing sands), cobbles, lost drilling fluid, lost ground, obstruction, fluid return color changes and equipment problems, and a discussion of the problem must be provided in the geotechnical report. The geotechnical report must provide details of the drilling method, drilling fluid, size of boreholes and the ground elevations at the top of the boreholes.

2. Test Pits or Trenches: Supplemental test pits or trenches must be located appropriately to provide visual inspection of soil layers, measurement of bedrock orientation and collection of bulk samples. ~~Test pits and trenches must be logged. Collection of block samples must be performed according to ASTM Standard D7015.~~ The geotechnical report must provide details of the method used for excavating test pits and the test pit logs must record any excavation problem observed such as instability of cut (sloughing, caving, etc.), depth of refusal, difficulty of excavating, etc.

3. Field Tests:

   a. Standard Penetration Tests (SPT): The standard penetration test must follow ASTM Standard D1586. ~~Standard penetration resistance (SPT N or N value) is the number of blows of a 140 lbm hammer falling 30 in. required to produce 1-foot of penetration of a specified (standard) 2-in. outside diameter, 13/8-in. inside diameter sampler into soil, after an initial 0.5 feet seating. A penetration test that does not meet these requirements is not a SPT and the penetration resistance must not be reported as a SPT N-value or N-value and care must be taken with its use for correlating soil properties.~~ Published correlations for SPT N-value cannot be used for non-SPT blow count numbers. If SPT N-values are used for the assessment of liquefaction potential, the SPT N-values must be normalized according to ASTM Standard D6066.

b. Cone Penetration Tests (CPT): CPT tests must be performed and results provided according to ASTM Standard D5778. Electronic data must be provided on a CD along with CPT logs and interpretations. CPT tests can be used to supplement site characterization.

c. Geophysical Investigation: Geophysical survey methods may be used to supplement borehole and outcrop data and to interpret soil profile between boreholes. They can be used to plan borehole locations. ASTM Standards D6429 and D5753 provide guidance on planning and selection of geophysical methods. ASTM Standard D5777 provides guidance on test procedures and interpretation of the seismic refraction method. ASTM Standard D4428/D4428M provides test methods and interpretation of the crosshole seismic test. The geotechnical report must explain the test method and interpretation of the test results.

d. Field Permeability Test: Field permeability testing is generally required for all proposed infiltration practices and may be required for other non-infiltrating stormwater BMPs. If a field permeability test is performed, details of the test method, calculations and interpretation must be included along with the results. Testing for saturated hydraulic conductivity shall be done in accordance with ASTM-D5126 "Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone". If the infiltration rate is measured with a *Double-Ring Infiltrometer* the requirements of ASTM-D3385 shall be used for the field test. Single ring or double ring infiltrometer are preferred test methods, however Borehole permeameter method is allowable in cases where test pit excavation depths or site constraints pose safety concerns.

1. Test log must state name of individual preforming test, date, type of test method, boring or test pit excavation method, air temperature, precipitation, depth below grade, elevation, diameter of boring and casing, depth of casing penetration.

2. For both constant and falling head test methods, a saturation period of 1 hour or a drop of 12 inches (approx. 30 cm) is required. After the saturation period, multiple test periods are measured and recorded until at least 2 consecutive runs are consistent. Each test period is to be a minimum of one hour or a drop of 12 inches. For falling head test method, each run is to starting at the same initial head to normalize the effect of head on the measured drop. The saturation period shall not be used in determining infiltration rate.

e. Measurement of Water Level in Boreholes: Water level must be measured in boreholes and test pits and shown accordingly on logs of the boreholes and test pits. The water level must be recorded during drilling and after the ground water table is stabilized. Both water levels must be provided on borehole logs along with the time of measurement. Elevation of the water table must be established based on the project datum and shown on the ground profile of the dam site.

f. Field tests with equipment such as pocket penetrometer and torvane are not acceptable for deriving design parameters. Equipment used in the geotechnical investigation must be used appropriately in accordance with ASTM standards.

4. Sample Collection for Laboratory Testing:

a. The sample collection program must be designed to meet the requirements of the laboratory tests planned for the project. Some laboratory tests require relatively undisturbed samples while others can use disturbed samples so long as the properties of the sample is preserved. Sample collection, preservation, transportation and handling must be described in the geotechnical report. Appropriate ASTM Standards D4220 and D5079 must be followed in collection and transport to prevent samples from experiencing excessive disturbance during transportation and handling.

b. Disturbance of samples inherent to sampling techniques must be recognized. Soil samples that are obtained by driving samplers with a hammer such as the standard penetration test (ASTM Standard D1586) and penetration of samplers lined with rings (ASTM Standard D3550) are considered highly disturbed. This must be recognized when interpreting and presenting results from laboratory tests based on these samples. If the soil samples for the laboratory tests were reconstituted in the laboratory, the method of sample preparation must be explained in detail.

c. Samples collected by a Thin-Walled Tube Sampler (ASTM Standard D1587) and other samplers specifically designed to minimize disturbance during sample collection process are recognized as undisturbed samples. Description of the sampler and sample collection method must be provided.

d. For block samples, the method of collection, preservation, transportation and handling must be described in the geotechnical report. If the method complies with ASTM standard D7015, the block samples will be considered undisturbed.

e. Rock samples must be collected following the procedures outlined in ASTM Standard D2113. Rock Quality Designation (RQD) determination of rock core must follow ASTM Standard D6032.

5. Soil Classification:

a. Soil classification must follow the Unified Soil Classification System as provided in ASTM Standard D2487.

b. Rock-mass classification must follow ASTM Standard D5878. A discussion must be provided on the selection of the classification system.

6. Laboratory Tests:

a. Consistency tests (Atterberg Limits) for fine-grained soil and sieve analysis for coarse-grained soil are the basic tests required for classification of soil and must be performed. Determination of density, water content and specific gravity is also required. Selection of other laboratory tests must be based on the requirements of the design project. A laboratory testing program must be developed while planning for the site investigation since it may dictate the selection of a boring method and sample collection. Limitations of the laboratory tests must be recognized in the laboratory testing program. Laboratory tests must follow appropriate ASTM standards.

~~b. Strength Testing:~~

~~i. Direct Shear Test (Consolidated Drained Shear Test): The direct shear test is one of the most popular shear strength tests as it provides relatively rapid determination of shear strength parameters and is less expensive to perform. However, the limitations of the test are often not recognized and/or the test method is not followed appropriately on many occasions making the test results of little value. ASTM Standard D3080 provides the test methodology and discusses specimen requirements, selection of appropriate shearing rate and presentation of the results. This standard must be followed to obtain credible shear strength parameters.~~ ~~**The direct shear test is not recommended on clayey soils.**~~ ~~Triaxial shear tests provide more accurate results for the clayey soils. The normal stress applied to the sample must represent the stress that the soil will be subjected to after construction. Soil samples must be consistent in unit weight and relative density (void ratio) since the strength of the soil varies with relative density.~~

~~ii. Unconfined Compression Test (UC Test): The unconfined compression test can be used to estimate the undrained shear strength of saturated, fine-grained foundation materials. The UC Test is applicable only for cohesive soils which will not expel or bleed water during the loading portion of the test and which will retain intrinsic strength after removal of confining pressures, such as clays or cemented soils. Dry and crumbly soils, fissured or varved soils, silts, peats, and sands cannot be tested with this method to obtain valid unconfined compression strength values. The test must follow ASTM Standard D2166. This test generally provides conservative strength parameters for the end-of-construction loading condition.~~

~~iii. Unconsolidated-Undrained Triaxial Compression Test (UU Test or Q Test): The UU Test is suitable for saturated fine-grained soils. The sample is not consolidated prior to testing and the water content of the soil is not allowed to change either prior to or during testing. This test method removes some of the limitations of the UC Test and is applicable to a wider range of fine-grained soils. ASTM Standard D2850 provides methodology for the UU Test. It is recommended that the UU Test on embankment soils be performed on samples remolded at the higher water content likely to be encountered during fill placement to represent the lowest embankment fill shear strength.~~

~~Descriptions must be provided about the source and preparation of the sample. The degree of saturation of the sample must be calculated and provided with the result. The reporting guideline provided by ASTM Standard D2850 must be followed. This test provides shear strength parameters suitable for the end-of-construction loading condition (total stress analysis).~~

~~iv. Consolidated-Undrained Triaxial Compression Test with Pore Pressure Measurement (CU Test or R Test): For the consolidated undrained test, the sample is saturated and consolidated under confining pressures that approximate field conditions. Pore water pressure during the test is measured to determine effective stress parameters. The consolidated undrained test can be performed on saturated impervious or semi-impervious soils and simulates the soil conditions experienced during steady-state seepage and rapid drawdown. ASTM Standard D4767 provides the test method for consolidated undrained triaxial compression test for cohesive soils.~~

~~v. Consolidated-Drained Triaxial Compression Test (CD Test or S Test): The CD Test is similar to CU Test except the shear stress is applied slowly to allow dissipation of excess pore pressure during the shearing process. Pore pressure measurements are not required. This test is suitable for free-draining soils and provides effective stress parameters. The test can also be performed on relatively impervious soils to model strength of the embankment materials above the phreatic line.~~

~~c. One-Dimensional Consolidation Test (Oedometer Test): Oedometer tests are performed on clayey soils to obtain consolidation parameters required for the estimation of consolidation settlement. Undisturbed soil samples are required for this test. The test specimen must be fully saturated. ASTM Standards D2435 and D4186 provide the test methods, analysis and reporting of results. If the oedometer is used for evaluating collapse potential of soils, follow ASTM Standard D5333.~~

~~d. Permeability Test: The sample preparation and the test method of the permeability test must be discussed in the report. ASTM Standard D2434 provides the methodology for the constant head test on granular soils. If the falling head test is used, it must be stated as such in the report. Relative density of the granular soil specimen must be reported with the result.~~

~~e. Dispersibility Test: ASTM Standards D4647 and D4221 provide methods of evaluating dispersive properties of clay soils. A description of the sample preparation and test method must be included in the report along with the discussion of the results.~~

~~f. Collapse Potential Test: ASTM Standard D5333 provides the methodology for evaluating collapse potential of soils. This standard must be followed for the test and interpretation of the results.~~

g. Compaction Tests: ASTM Standards D698 and D1557 provide methods for the Standard Proctor and Modified Proctor, respectively, for the laboratory evaluation of compaction characteristics of soils containing up to 30 percent coarse materials by weight retained on the ¾-inch sieve. If the soil contains over 5 percent coarse particles retained on the ¾-inch sieve and the coarse particles are not included in the Proctor tests, it must be mentioned in the test results and a correction for the oversize curves must show all the data points along with the interpreted curve. The 100-percent saturation curve (zero air voids curve) must also be shown on the graph with the compaction curve. The sample preparation and test method must also be explained. If the soil contains more than 30 percent oversize particles retained on the ¾-inch sieve or the soil particles break during the compaction test changing gradation significantly compared to the field compaction, or the soil is gap graded, concurrence must be obtained in advance from the DNREC Sediment & Stormwater Program on the approach and the method to be used for the compaction evaluation of such soils.

D. The following information shall be recorded for Step B:

1. The date or dates the data was collected.
2. A legible site plan/map that is presented on paper that is no less than 8 ½ X 11 inches in size and:

   a. Is drawn to scale or fully dimensional.
   b. Illustrates the entire development site.
   ~~c. Shows all areas of planned filling and/or cutting.~~
   ~~d.~~c. Includes a permanent vertical and horizontal reference point.
   ~~e. Shows the percent and direction of land slope for the site or contour lines; highlight areas with slopes over 20%.~~
   ~~f. Shows all flood plain information that is pertinent to the site.~~
   ~~g.~~d. Shows the location of all pits/borings included in the report.
   ~~h. Location of wetlands as field delineated and surveyed.~~
   ~~i.~~e. Location of karst features, private wells within 100 feet of the development site, and public wells within 400 feet of the development site.

3. Soil profile descriptions must be written in accordance with the descriptive procedures, terminology and interpretations found in the Field Book for Describing and Sampling Soils, USDA, NRCS, 1998. Frozen soil material must be thawed prior to conducting evaluations for soil color, texture, structure and consistency. In addition to the data determined in Step B, soil profiles must include the following information for each soil horizon or layer:

   a. Thickness, in inches or decimal feet.
   b. ~~Munsell~~ soil color notation.
   c. Soil mottle or redoximorphic feature color, abundance, size and contrast.
   ~~d. USDA soil textural class with rock fragment modifiers.~~
   ~~e.~~d. Soil structure, grade size and shape.
   ~~f.~~e. Soil consistence, root abundance and size.
   ~~g. Soil boundary.~~
   ~~h.~~f. Occurrence of saturated soil, groundwater, bedrock or disturbed soil.

4. The following additional information shall be provided for geotechnical investigations:
   a. Soil classification in accordance with the Unified Soil Classification System.
   b. Results of applicable tests conducted in accordance with Step B, Part C.
   c. Assessment of suitability of on-site soils for construction of proposed stormwater BMPs.
   d. Compaction requirements, as applicable.
   e.

Step C. Evaluation of Specific Infiltration Areas

This step is to determine if locations identified for infiltration practices are suitable for infiltration, and to provide the required information to design the practice.

A minimum number of borings or pits shall be constructed for each infiltration device (see Table 1)~~.~~. The following information shall be recorded for Step C:

1. All the information under Step B.C. and B.D~~3~~. This includes all Borehole/test pit information as well as a legible site plan/boring location map.

~~2. A legible site plan/map that is presented on paper no less than 8 1/2 X 11 inches in size and:~~

   ~~a. Is drawn to scale or fully dimensional.~~
   ~~b. Illustrates the location of the infiltration devices.~~
   ~~c. Shows the location of all pits and borings.~~
   ~~d. Shows distance from facility to wetlands.~~

2. A vertical separation of two (2) feet from the seasonal high groundwater elevation is required for all infiltration practices unless an underdrain is provided. Long linear infiltration trenches such as perforated stormdrain shall be considered to have an underdrain if the pipe envelope has a positive outlet.
3. An analysis of groundwater mounding potential is required for certain classes of infiltration practices, as indicated in Table 1. Analysis of groundwater mounding potential may be considered on a case by case basis where practices without an underdrain are proposed within two (2) feet of seasonal high groundwater. The altered groundwater level, based on mounding calculations, must be considered in determining the vertical separation distance from the infiltration surface to the *highest anticipated groundwater elevation*. References include but are not limited to Finnemore 1993 and 1995, and Hantush 1967.

~~3.~~4. Groundwater elevation data may be supplemented by the installation of piezometers and the collection of groundwater level data for a minimum of one year. Data collected should be correlated to historical groundwater level data from the nearest Delaware Geological Survey (DGS) monitoring well.

~~4.~~5. The following procedures shall be used to determine the design infiltration rate:

a. Measured Infiltration Rate – Infiltration practices used for compliance purposes under the DSSR require field measured infiltration rates unless the use of an assumed rate is granted prior approval in accordance with Step C.4.b.. The tests shall be conducted at the least permeable soil horizon within three (3) feet of the bottom of the facility.

b. Assumed Infiltration Rate - Table 2 contains representative infiltration rates based on soil texture. These rates may be used for designing small scale practices in lieu of field infiltration testing with prior approval from the Department and/or Delegated Agency. Select the infiltration rate from Table 2 based on the soil horizon at the bottom elevation of the proposed infiltration facility.

c. Correction Factor - The infiltration rate shall be divided by a correction factor to determine the final rate to be used for design purposes. The correction factor adjusts the infiltration rates for the occurrence of less permeable soil horizons below the bottom of the facility and the potential variability in the subsurface soil horizons throughout the infiltration site. ~~A less permeable soil horizon below the location of the measurement increases the level of uncertainty in the measured value. Also, the uncertainty in a measurement is increased by the variability in the subsurface soil horizons throughout the proposed infiltration site.~~ The infiltration rate shall be divided by a correction factor in accordance with the following guidelines:

   i If measured rates are used, the rate determined during field testing is divided by 2.0 to determine the final design infiltration rate. ~~For example, if field testing results indicated a measured infiltration rate of 1.80 in/hr at the least permeable soil horizon within three (3) feet of the bottom of the facility, the final design infiltration rate would be 1.80/2.0 = 0.90 in/hr.~~

   ii If the use of non-measured rates has been authorized, the ratio is based on the rate from Table 2 for the soil textural classification of the soil horizon at the bottom of the facility divided by the rate for the soil textural classification of the least permeable soil horizon within three (3) feet of the bottom of the facility. The final design infiltration rate is then determined from Table 3 based on this ratio. For example, a facility with a sand at the bottom of the facility (3.60 in/hr) and a least permeable layer of loamy sand (1.63 in/hr) will have a design infiltration rate ratio of about 2.2 and a correction factor of 4.0. The final design infiltration rate would therefore be 3.60/4.0 = 0.90 in/hr.

5. The minimum infiltration rate without correction factor for all runoff reduction and infiltration practices is 1.0 in/hr. To determine if infiltration is not feasible in a specific location, at least one of the following criteria must be satisfied:
   a. The area is classified as “Poor” under the Runoff Reduction Feasibility mapping, or
   b. The least permeable soil horizon three (3) feet below the bottom of infiltration system is one of the following: sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, or clay, or

c. A field testing method conducted in accordance with this document indicates an infiltration rate less than 1.0 in/hr. The infiltration rate used to claim the exemption shall be the actual field measurement and shall be used without the correction factor applied.

Step D. Soil and Site Evaluation Report Contents

The site's legal description and all information required in Steps B and C shall be included in the Soil and Site Evaluation Report. These reports shall be completed prior to the *construction plan* submittal. Table 1 summarizes the evaluation requirements for various types of infiltration practices.

Table 1: Evaluation Requirements Specific to Proposed Infiltration Devices

Infiltration Practice	Tests Required[1]	Minimum Number of Borings/Pits Required	Minimum Drill/Test Depth Required Below the Bottom of the Infiltration System
Infiltration Trenches (< 10,000 sq ft impervious drainage area)	Pits required on central systems; borings permissible for distributed systems	1 test required up to 500 linear feet and one (1) additional boring per 250 linear feet of trench, and sufficient to determine variability.	3 feet or depth to limiting layer, whichever is less.
Infiltration Trenches (> 10,000 sq ft impervious drainage area)	Pits required on central systems; borings permissible for distributed systems	1 test required up to 250 linear feet and one (1) additional boring per 250 linear feet of system, and sufficient to determine variability.	3 feet or depth to limiting layer, whichever is less.
Infiltrating Bioretention Systems	Pits required on central systems; borings permissible for distributed systems	1 test required up to 250 linear feet and one (1) additional boring per 250 linear feet of system, and sufficient to determine variability.	3 feet or depth to limiting layer, whichever is less.
Surface Infiltration Basins	• Pits required on central systems; borings permissible for distributed systems • Mounding analysis on case-by-case basis	1 test required per infiltration area with an additional boring for every 25,000 square feet of infiltration area, and sufficient to determine variability.	3 feet or depth to limiting layer, whichever is less.
Subsurface Dispersal Systems	• Pits required on central systems; borings permissible for distributed systems • Mounding analysis on case-by-case basis	1 test required per infiltration area with an additional boring for every 10,000 square feet of infiltration area, and sufficient to determine variability.	3 feet or depth to limiting layer, whichever is less.

[1]Continuous soil borings shall be taken using a bucket auger, probe, split-spoon sampler, or shelby tube. Samples shall have a minimum 2-inch diameter. Soil pits must be of adequate size, depth and construction to allow a person to enter and exit the pit and complete a morphological soil profile description.

Table 2: Assumed Infiltration Rates for Soil Textures Receiving Stormwater

Soil Texture[1]	**Infiltration Rate Without Measurement inches/hour[2]**
Coarse sand or coarser	3.60
Loamy coarse sand	3.60
Sand	3.60
Loamy sand	1.63
Sandy loam	0.50
Loam	0.24
Silt loam	0.13
Sandy clay loam	0.11
Clay loam	0.03
Silty Clay loam	0.04[3]
Sandy clay	0.04
Silty clay	0.07
Clay	0.07

[1]Use sandy loam design infiltration rates for fine sand, loamy fine sand, very fine sand, and loamy fine sand soil textures.

[2] Infiltration rates represent the lowest value for each textural class presented in Table 2 of Rawls, 1998.

[3] Infiltration rate is an average based on Rawls, 1982 and Clapp & Hornberger, 1978.

Table 3: Correction Factors for Assumed Infiltration Rates

Ratio of Infiltration Rates[1]	**Correction Factor**
≤1	3.0
1.1 to 4.0	4.0
4.1 to 8.0	5.0
8.1 to 16.0	6.0
16.1 or greater	8.0

[1]Ratio is determined by dividing the design infiltration rate (Table 2) for the textural classification at the bottom of the infiltration facility by the design infiltration rate (Table 2) for the textural classification of the least permeable soil horizon. The least permeable soil horizon used for the ratio should be within three (3) feet of the bottom of the facility or to the depth of the limiting layer.

Required Qualifications

A. Infiltration Testing – Individuals performing infiltration testing in accordance with these procedures shall possess a Class A On-Site License issued by the DNREC Groundwater Discharges Section.

B. Site Investigations - Individuals completing site investigations shall possess a Class D (Soil Scientist) On-Site License issued by the DNREC Groundwater Discharges Section and have experience in soil investigation, interpretation and classification.

C. Site Evaluations - Individuals completing the site evaluation report shall be a licensed Soil Scientist, licensed Geotechnical Engineer, licensed Geologist or other licensed professional having the necessary knowledge, skills and training within their area of expertise to interpret the results of the site investigation and render the appropriate recommendations.

For the purposes of these procedures, individuals with higher credentials are assumed to be qualified to perform work at a level that requires lower credentials. For example, an individual that possesses a Class D license would also be authorized to perform infiltration testing.

VI. References

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VII. Definitions

Bioretention systems (Table 1): Bioretention is an infiltration device consisting of an excavated area that is back-filled with an engineered soil, covered with a mulch layer and planted with a diversity of woody and herbaceous vegetation. Storm water directed to the device percolates through the mulch and engineered soil, where it is treated by a variety of physical, chemical and biological processes before infiltrating into the native soil.

Construction Plan (V.Step D): A map and/or plan describing the built-out features of an individual lot.

Coarse sand (V.Step B.B.1): Soil material that contains 25% or more very coarse and coarse sand, and <50% any other one grade of sand.

Design infiltration rate (II.3): A velocity, based on soil structure and texture, at which precipitation or runoff enters and moves into or through soil. The design rate is used to size an infiltration device or system. Rates are selected to be minimal rates for the different types of soils. Selection of minimal rates will provide a robust design and maximize the longevity of the device.

Development site (I.1): The entire area planned for development, irrespective of how much of the site is disturbed at any one time or intended land use. It can be one lot or multiple lots.

Double-ring infiltrometer (V.Step C.4.b): A device that directly measures infiltration rates into a soil surface. The double-ring infiltrometer requires a fairly large pit excavated to depth of the proposed infiltration device and preparation of a soil surface representative of the bottom of the infiltration area.

High groundwater level (V.Step A.4): The higher of either the elevation to which the soil is saturated as observed as a free water surface in an unlined hole, or the elevation to which the soil has been seasonally or periodically saturated as indicated by soil color patterns throughout the soil profile.

Highest anticipated groundwater elevation (V.Step C.3): The sum of the calculated mounding effects of the discharge and the seasonal high groundwater level.

Infiltration areas (V): Areas within a development site that are suitable for installation of an infiltration device.

Infiltration basin (Table 1): An open impoundment created either by excavation or embankment with a flat densely vegetated floor. It is situated on permeable soils and temporarily stores and allows a designed runoff volume to infiltrate the soil.

Infiltration trench (Table 1): An excavated trench that is usually filled with coarse, granular material in which stormwater runoff is collected for temporary storage and infiltration. Other materials such as metal pipes and plastic domes are used to maintain the integrity of the trench.

Irrigation system (Table 1): A system designed to disperse stored stormwater to lawns or other pervious areas.

Limiting layer (Table 1): A limiting layer can be bedrock, an aquatard, aquaclude or the seasonal high groundwater table.

Percent fines (V. Step B.B): the percentage of a given sample of soil, which passes through a # 200 sieve.

Regional device (V.Step A): An infiltration system that receives and stores stormwater runoff from a large area. Infiltration basins are the most commonly used regional infiltration devices.

Redevelopment (V.Step A.6): Areas where new development is replacing older development.

Runoff reduction practice (II.2): Sometimes used synonymously with infiltration practice. A structure or mechanism engineered to facilitate the entry and movement of precipitation or runoff into or through the soil. Examples of runoff reduction practices include infiltration trenches, infiltrating bioretention systems, infiltration basins, and subsurface dispersal systems..

Soil parent material (V.Step A.3): The unconsolidated material, mineral or organic, from which the solum develops.

Subsurface dispersal systems (Table 1): An exfiltration system that is designed to discharge stormwater through piping below the ground surface, but above the seasonal high groundwater table.