Borehole Infiltration Testing Guidelines

2.4.7 Borehole Infiltration Testing

2.4.7.1 General

Infiltration test results are utilized by Design personnel to assess the suitability of a site for various stormwater best management practices (BMPs). Borehole infiltration testing is a method that can be used to estimate infiltration rates required to properly design a BMP. Design considerations and engineering parameters for infiltration testing are discussed in Section 4.4.3.

2.4.7.2 BMP Site Characterization

An understanding of the soil profile, groundwater table, and depth to bedrock is required to determine the appropriate depth(s) for infiltration testing. This is typically achieved through advancement of one or more standard test borings in or near the footprint of the proposed BMP. The exploration plan developed for the project will include test borings located for this purpose. Subsurface conditions should be communicated with the geotechnical engineer prior to performing infiltration tests so that any required adjustments can be made.

2.4.7.3 Depth of Infiltration Testing

Site characterization activities described above are intended to facilitate selection of the actual test depth(s). In general, the preferred test depth interval is between the base of the proposed infiltrator (bottom of practice) and two feet below. Modifications to the test interval may be required for various reasons including the minimum depth required for proper seating/sealing of the casing; the existence of topsoil, organics, low permeability (clayey) or free draining soil at the proposed design interval; and shallow bedrock or groundwater. Communication between the field inspector and geotechnical engineer is critical to ensure that site conditions and design constraints are considered during performance of infiltration testing.

2.4.7.4 Borehole Infiltration Test Procedure

The borehole falling-head infiltration test utilized by the Department to estimate infiltration rates is a variation of the test described in NHDES Alteration of Terrain (AOT) rule Env-Wq 1504.14 (e)(4). The test is conducted within conventional drill casing advanced using drive and wash method to the design test interval as described below. A single trial consists of measuring the drop in water level over time for a maximum of one hour. A complete infiltration test generally consists of three or four one-hour trials in accordance with the following procedure:

1. Infiltration testing is conducted in 4” casing.
2. Advance casing to top of test interval using conventional geotechnical sampling techniques. Depending on proximity to adjacent test boring(s), the geotechnical engineer may waive sampling above the test interval. However, similar soil conditions should be confirmed from the cuttings during drive and wash.

3. Perform standard penetration test (SPT) through the test interval (2 feet) and retain sample for sieve analysis.
4. Advance casing to bottom of test interval and clean the test hole to remove as much loose material as possible. Record the height of any material remaining in the bottom of the casing before adding well sand in next step.
5. Start with a pre-measured volume of well sand, equivalent to a 2 foot cylinder with a diameter equal to the outside diameter of the casing. Pour the sand into the casing while withdrawing the casing 2 feet. The final level of sand should be at or just above the bottom of casing when the casing has been fully withdrawn. Estimate the amount of leftover sand or the amount of additional sand required to reach this level and record on the worksheet.
6. Record depths to top and bottom of test interval from ground surface. Record the height of casing from ground surface.
7. Add water to top of casing. Allow the test interval to soak for at least 30 minutes, refilling to the top of casing if needed.
8. After the pre-soaking period, ensure that the water is at the top of casing and immediately begin the test. Measure the depth to the water level within the casing and the time elapsed, at the time increments below, for a one-hour period or until the casing is fully drained:
    - First 16 minutes – 1 measurement per minute
    - 1 measurement at 18 minutes, and 1 at 20 minutes
    - Remainder of test – 1 measurement per 5 minutes
9. Repeat the test procedure three additional times, for a total of four individual trials. All trials should be run consecutively until completed. The geotechnical engineer should be consulted for any conditions that may warrant a reduction in the total number of tests based on the initial test results.
10. If testing of additional depth-intervals is required, advance the hole and repeat the above procedure. Complete the test boring as directed by the geotechnical engineer.

Chapter 4 – Geotechnical Engineering Analysis

4.4 Detention Basins

4.4.3 Infiltration

Add: **4.4.3.1 General**

Preserving the quality of receiving waters for stormwater runoff is an increasingly important factor in drainage design. Infiltration rates are utilized by Design personnel to assess the suitability of a site for various stormwater best management practices (BMPs). The need for infiltration information is expected to increase as the Department implements appropriate long-term stormwater management and treatment practices in accordance with state and federal regulations. There are a number of techniques that can be utilized to predict an infiltration rate for a BMP site. This section pertains to infiltration rates determined using the borehole infiltration test described in Section 2.4.7.4. Other techniques that can be used to check or supplement field test data are discussed in Env-Wq 1504.14.

4.4.3.2 Number and Location of Test Borings

An understanding of the soil profile, groundwater table, and depth to bedrock is required to determine the appropriate depth(s) for infiltration testing. Typically this is achieved through advancement of one or more standard test borings in or near the footprint of the proposed BMP. The exploration plan developed for the project should include test borings located for this purpose. Test borings outside the footprint may be needed depending on the surrounding topography and expected subsurface conditions (e.g. if outcrops are observed, sloping terrain, etc.). The minimum number of test borings (or test pits) for a proposed BMP is prescribed in the NHDES Alteration of Terrain (AOT) rules as follows (ref. Env-Wq 1504.13 (c)):

- At least one in each infiltration basin area < 2,500 SF
- At least two in each infiltration basin area 2,500 SF or greater, with an additional boring in every 10,000 SF of basin area
- At least one in each infiltration trench, with an additional boring in each 100 LF of trench

The number of test borings may be reduced for very large basins if, in the judgement of the Design team, adequate subsurface information is available.

Test boring data is used to determine the feasibility of infiltration testing at a specific depth interval(s) through an assessment of soil parameters, groundwater conditions, and depth to bedrock if within 5 feet below the bottom of the practice. An observation well should be installed if more accurate or long-term variations in groundwater levels are required. Site constraints or significant adjustments may need to be discussed with the Design team.

4.4.3.3 Number and Depth of Infiltration Tests

Field infiltration tests are located within the footprint of the proposed practice, sufficiently spaced to be representative of the overall conditions. The number of tests is prescribed in the AOT rules as follows (ref. Env-Wq 1504.14 (f)):

- For infiltration basins:
    - One field test in every 2,500 SF of area if no manmade soils are present;
    - One field test in every 1,000 SF of area for basins located on existing manmade soils.
- For infiltration trenches:
    - One field test in every 100 LF of trench if no manmade soils are present;
    - One field test in every 50 LF of trench if located on existing manmade soils.

The number of infiltration tests may be reduced for very large basins if, in the judgement of the Design team, adequate permeability information is available.

The infiltration testing depth is influenced by a number of factors. The preferred depth is established through discussions between the geotechnical engineer and the Design team and is typically designated as the depth interval between the base of the proposed infiltrator (bottom of the practice) and two feet below. Modifications to the test interval may be required for various reasons including but not limited to the following:

- The design test interval occurs in the upper organic rich topsoil/subsoil, which will typically be removed prior to construction of the infiltrator/practice and is therefore not representative of the soils that will be present for infiltration. In this case, the test interval is shifted deep enough to complete the test in the natural, inorganic soils.
- The design test interval occurs at a depth that does not provide sufficient casing embedment such that the water added during the test escapes from around the casing-soil interface to the ground surface, or in locations below the ground surface other than thru the test interval. Soil type and drilling technique can greatly affect the minimum required embedment. Typically, a minimum of four feet is required to provide sufficient casing embedment.
- The design test interval occurs in low permeability (clayey) soil, free draining soil (coarse sand/gravel), at or below the groundwater table, or within 5 feet of bedrock.

In some cases, the test depth is selected in order to get a general estimate of infiltration potential at a site, i.e. the bottom of practice has not yet been determined.

Refer to Section 2.4.7.4 for the borehole infiltration test procedure.

4.4.3.4 Determination of Design Infiltration Rates

The current AOT rules define the design infiltration rate as the saturated hydraulic conductivity (k_{sat}) multiplied by a factor of safety of 0.5. The procedure for determining k_{sat} from borehole infiltration test data is not prescribed. Instead, the average one-hour drop in water elevation (or the final one-hour drop, if lower) is designated as the infiltration rate.

The Geotechnical Section calculates the permeability k in accordance with the Hvorslev time-lag method [2]. This document includes formulas for determination of coefficients of permeability for various head, borehole, and test conditions. Case G (Well Point-Filter in

Uniform Soil) is appropriate for the falling-head (variable head) test method utilized by the Geotechnical Section as summarized in Section 2.4.7.4:

$$k = \frac{d^2 \ln\left[\frac{mL}{D} + \sqrt{1 + \left(\frac{mL}{D}\right)^2}\right]}{8L(t_2 - t_1)} \ln\frac{H_1}{H_2}$$

or

$$k = \frac{d^2 \ln\left(\frac{2mL}{D}\right)}{8L\,(t_2 - t_1)} \ln\frac{H_1}{H_2} \qquad for\ \frac{mL}{D} > 4$$

where:

d = standpipe diameter (I.D. of casing)
D = intake zone diameter (O.D. of casing)
H_1 = piezometric head at t_1
H_2 = piezometric head at t_2
L = intake length (test interval - typ. 2 feet)
m = transformation ratio = $\sqrt{k_h/k_v}$ = 1 (k_h and k_v are assumed equal)
$t_2 - t_1$ = time interval

The design infiltration rate is calculated as k times a factor of safety of 0.5. Calculated infiltration rates should be compared to saturated permeability (k_{sat}) values available through the NRCS (Web Soil Survey) for soils native to the location of the BMP.

4.4.3.5 Additional Considerations

Infiltration practices are prohibited in the following areas: (ref. Env-Wq 1508.06 (a)):

i. Areas identified in Env-Wq 1507.02. It is assumed that conformance with this criteria is determined by the Bureau of Highway Design or its consultants;
ii. Soils where the infiltration rate, prior to adding a factor of safety, is less than 0.5 inches per hour;
iii. Soils where the infiltration rate, prior to adding a factor of safety, is greater than 10 inches per hour with field infiltration rates. However, such soils may be acceptable if the soils are amended or the stormwater is pretreated (ref. Env-Wq 1508.06)

4.4.3.6 Reporting

The Geotechnical Section reports both raw infiltration test data (one-hour totals with average) and calculated infiltration rates to the Design team. A summary of tests performed including casing diameter and depth interval(s) and the method used to calculate the infiltration rate should be provided. This information is typically sent during the design phase via email and included in the final Geotechnical Report for the

project. The final report should include a discussion of the proposed BMP, general site conditions, and subsurface exploration data.

References:

1. New Hampshire Department of Environmental Services (NHDES) Administrative Rules, Chapter Env-Wq 1500, Alteration of Terrain
2. Hvorslev, M. (1951) Time Lag and Soil Permeability in Ground-Water Observations, Bulletin No. 36, Waterways Experiment Station, USACOE, Vicksburg, Mississippi