Assessing Soil for Stormwater Infiltration

CLEAN WATER SUMMIT 2012

Green Infrastructure for Clean Water: The Essential Role of Soil

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Definitions according to the McGraw-Hill Dictionary of Scientific and Technical Terms 5th Ed.

• Soil
  – Unconsolidated rock material over bedrock.
  – Freely divided rock-derived material containing an admixture of organic matter and capable of supporting vegetation.

• Water
  – Clear, odorless, tasteless liquid that is essential for most animal and plant life and is an excellent solvent for many substances.

• Storm Water
  – No Definition Given

• Storm Sewage
  – Refuse liquids and waste carried by sewers during or following a period of heavy rainfall.

• Infiltration
  – Movement of water through the soil surface into the ground.
Soil Assessments - Desktop

- Geotechnical reports
  - Site specific
  - “Drilled to Build”
- County soil surveys
  - Detailed profile
  - Upper 5 feet
  - More “Grow than Flow”
- Geologic atlases and maps
- Well records
- Aerial photographs
Soil Classification

Unified Soil Classification
(Engineering)

USDA Classification
(Agriculture)
### Table 12-INF.7 Design Infiltration Rates

<table>
<thead>
<tr>
<th>Hydrologic Soil Group</th>
<th>Soil Textures*</th>
<th>Corresponding Unified Soil Classification**</th>
<th>Infiltration Rate [inches/hour]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Gravel, sand, sandy gravel, silty gravel, loamy sand, sandy loam</td>
<td>GW – Well-graded gravel or well-graded gravel with sand GP – Poorly graded gravel or poorly graded gravel with sand</td>
<td>1.63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GM – Silty gravel or silty gravel with sand</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SW – Well-graded sand or well-graded sand with gravel</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SP – Poorly graded sand or poorly graded sand with gravel</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Loam, silt loam</td>
<td>SM – Silty sand or silty sand with gravel</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ML – Silt</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>OL – Organic silt or organic silt with sand or gravel or gravelly organic silt</td>
<td>0.3</td>
</tr>
<tr>
<td>C</td>
<td>Sandy clay loam</td>
<td>GC – Clayey gravel or clayey gravel with sand</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SC – Clayey sand or clayey sand with gravel</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Clay, clay loam, silty clay loam, sandy clay, silty clay</td>
<td>CL – Lean clay or lean clay with sand or gravel or gravelly lean clay</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CH – Fat clay or fat clay with sand or gravel or gravelly fat clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>OH – Organic clay or organic clay with sand or gravel or gravelly organic clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MH – Elastic silt or elastic silt with sand or gravel</td>
<td></td>
</tr>
</tbody>
</table>
So why do a field assessment?!?

- The soil’s rate is in the table…
- It’s not in the budget…
- Just look at the boring cross-sections…
- It worked across the street…
- It doesn’t cost much to fix…
- Nobody will sue me if it fails…
- All soils are the same…
Ranges of Hydraulic Conductivities

**Silty Sand**

12% to 50% P-200 (silt and clay)

$10^{-5}$ to $10^{-1}$ cm/s (conductivities)

Source:
Freeze & Cherry, *Groundwater*, 1979
Soil Assessments - Field

• Soil Borings
  – Hand Augers
  – Standard Penetration
  – Push Probes
  – Cone Penetrometer

• Test Pits
Soil Borings vs. Test Pits
ASTM: D 1586 – Split Spoon

- Split-Barrel Sampler (18 to 30 inches)
- Test Intervals typically 5 feet or less
- 140-lb hammer (± 2 lbs)
- 30-in drop (± 1 in)
- Count the ‘blows’ for each 0.5 foot
- Stop when:
  - Total of 50 blows for any 0.5 foot interval
  - Total of 100 blows
  - No advance after 10 blows
  - Sampler is advanced the “complete 1.5 feet”
Boring Logs

- Sample interval
- Grain size descriptions
- Lenses of differing soils types
- Gradation results
- Recovery
- Blow counts
- Water levels
- DATE
Infiltration Boring Specifications

• Continuous Sampling: 0-2, 2-4, 4-6, ....

• Full 2-foot drives: 2 feet, not 18 inches

• Particle Size Distribution Tests
  – Sieves only (silt and clay lumped together – P200)
  – Hydrometer (defines silt and clay fractions separately)

• Depth, Number and Location
  – WDNR Table – Infiltration Practice Evaluation Requirements
  – Professional judgment
<table>
<thead>
<tr>
<th>Infiltration Device</th>
<th>Tests Required</th>
<th>Minimum Number of Borings/Pits Required</th>
<th>Minimum Drill/Test Depth Required Below the Bottom of the Infiltration System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation Systems</td>
<td>Pits or borings</td>
<td>NA</td>
<td>5 feet or depth to limiting layer, whichever is less.</td>
</tr>
<tr>
<td>Rain Garden</td>
<td>Pits or Borings</td>
<td>NA</td>
<td>5 feet or depth to limiting layer, whichever is less.</td>
</tr>
<tr>
<td>Infiltration Trenches (&lt; 2000 sq ft impervious drainage area)</td>
<td>Pits or borings</td>
<td>1 test/100 linear feet of trench with a minimum of 2, and sufficient to determine variability</td>
<td>5 feet or depth to limiting layer, whichever is less.</td>
</tr>
<tr>
<td>Infiltration Trenches (&gt; 2000 sq ft of impervious drainage area)</td>
<td>• Pits or borings, • Mounding potential</td>
<td></td>
<td>Pits to 5 feet or depth to limiting layer Borings to 15 feet or depth to limiting layer</td>
</tr>
<tr>
<td>Bioretention Systems</td>
<td>• Pits or borings, • Mounding potential</td>
<td>1 test/50 linear feet of device with a minimum of 2, and sufficient to determine variability</td>
<td>5 feet or depth to limiting layer</td>
</tr>
<tr>
<td>Infiltration Grassed Swales</td>
<td>Pits or borings</td>
<td>1 test/1000 linear feet of swale with a minimum of 2, and sufficient to determine variability</td>
<td>5 feet or depth to limiting layer</td>
</tr>
<tr>
<td>Surface Infiltration Basins</td>
<td>• Pits or borings, • Mounding potential</td>
<td>2 pits required per infiltration area with an additional 1 pit or boring for every 10,000 square feet of infiltration area, and sufficient to determine variability</td>
<td>Pits to 10 feet or depth to limiting layer Borings to 20 feet or depth to limiting layer</td>
</tr>
<tr>
<td>Subsurface Dispersal Systems greater than 15 feet in width.</td>
<td>• Pits or borings, • Mounding potential</td>
<td>2 pits required per infiltration area with an additional 1 pit or boring for every 10,000 square feet of infiltration area, and sufficient to determine variability</td>
<td>Pits to 10 feet or depth to limiting layer Borings to 20 feet or depth to limiting layer</td>
</tr>
</tbody>
</table>
Laboratory Tests

- Grain Size
  - Hazen Formula
  - Kozeny-Carman
  - Multiple others

- “Perm” Test
  - “Undisturbed” samples
  - Constant Head
    - Sands and gravels
  - Falling Head
    - Silts and clays
Field Tests

- “Perc” test
- Permeameter
- Single Ring Infiltrometer
- Modified Philip-Dunne Infiltrometer
- Double Ring Infiltrometer
- Pit or Basin

http://www.rickly.com/MI/Infiltrometer.htm
Pit/Basin Tests

- Preferred test
- Reduces local affects
- Larger area
  - ~100 ft² for trench box
  - 3.14 ft² for double-ring
- Correction factors
  - Same for Stormwater
  - 7 to 10% for Wastewater
- Drawbacks
  - No ASTM
  - Large volume of water
  - Outer ring?
  - Cost?
Waste water – Soil Aquifer Treatment (SAT)

“Cylinder infiltrometers greatly overestimate operating infiltration rates. When cylinder infiltrometer measurements are used, annual hydraulic loading rates should be no greater than 2 to 4 percent of the minimum measured infiltration rates.”

EPA/625/R-06/016, September 2006
Process Design Manual: Land Treatment of Municipal Wastewater Effluents

Minnesota Stormwater Manual

Table 12.INF.8 Total Correction Factors Divided into Measured Infiltration Rates

<table>
<thead>
<tr>
<th>Ratio of Design Infiltration Rates</th>
<th>Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>1.1 to 4.0</td>
<td>3.5</td>
</tr>
<tr>
<td>4.1 to 8.0</td>
<td>4.5</td>
</tr>
<tr>
<td>8.1 to 16.0</td>
<td>6.5</td>
</tr>
<tr>
<td>16.1 or greater</td>
<td>8.5</td>
</tr>
</tbody>
</table>

1 The method used to evaluate measured infiltration rates was developed by the Wisconsin Department of Natural Resources and is published in Site Evaluation for Stormwater Infiltration (1002) Wisconsin Department of Natural Resources Conservation Practice Standards 02/04.

2 Ratio is determined by dividing the design infiltration rate (Table 12.INF.9) for the textural classification at the bottom of the infiltration device by the design infiltration rate (Table 12.INF.9) for the textural classification of the least permeable soil horizon. The least permeable soil horizon used for the ratio should be within five feet of the bottom of the device or to the depth of the limiting layer.
Case Study # 1 – Infiltration Pond

- Residential development
- Mississippi River bluffs (Hastings)
- More than 40 feet of underlying sand

Limiting layer of topsoil and turf placed at the surface
Case Study 1A - Topsoil

1 Day

3 Days

7 Days

12 Days
Case Study 1A - Topsoil

17 Days

49 Days

61 Days

75 Days
Case Study # 2 – Septic Field

Buried Topsoil???
# Case Study #2 – Septic Field

## Subsurface Boring Log

<table>
<thead>
<tr>
<th>Depth (Ft)</th>
<th>Surface Elevation</th>
<th>Material Description</th>
<th>Geology</th>
<th>WC</th>
<th>Sample Type</th>
<th>Resist.</th>
<th>Field/Laboratory Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Fill, mixture of sand with silt and silty sand, a little gravel, possible cobbles, trace roots, brown</td>
<td>FILL</td>
<td>M</td>
<td>SS</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>SAND, a little gravel, fine to medium grained, light grayish brown, moist, loose (SF)</td>
<td>9</td>
<td>M</td>
<td>SS</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>SAND WITH GRAVEL, fine to medium grained, light grayish brown, moist, medium dense (SF)</td>
<td>6</td>
<td>M</td>
<td>SS</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>SAND WITH SILT AND GRAVEL, medium to fine grained, light grayish brown, moist, medium dense (SF)</td>
<td>13</td>
<td>M</td>
<td>SS</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>SAND WITH GRAVEL, medium to fine grained, brown to light brownish gray, moist, dense (SF)</td>
<td>17</td>
<td>M</td>
<td>SS</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>SAND WITH SILT AND GRAVEL, medium to fine grained, light brownish gray, moist, dense (SF-SM)</td>
<td>16</td>
<td>M</td>
<td>SS</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>

### Water Level Measurements

<table>
<thead>
<tr>
<th>Depth</th>
<th>Drilling Method</th>
<th>Date</th>
<th>Time</th>
<th>Sample Depth</th>
<th>Drilled Depth</th>
<th>Water Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2'</td>
<td>3.75&quot; USA</td>
<td>11/10/06</td>
<td>9:45</td>
<td>22.0</td>
<td>22.0</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11/10/06</td>
<td>10:20</td>
<td>26.0</td>
<td>26.0</td>
<td>20.0</td>
</tr>
</tbody>
</table>

**Completed:** 11/10/06

**Note:** Refer to the attached sheets for an explanation of terminology on this log.

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![Fill](image1)

![Buried Topsoil](image2)

![Sand](image3)

$I = 0$ in/hr

$I = 30$ in/hr
What Happened?

• ASTM: D 1586 Split Barrel Method only specifies driving 1.5 feet, not the full 2 feet
• Was the buried topsoil included in fill description?
• Was the entire sample collected for review?
• Was the layer not there?

Lessons

• Test pits and double-rings (at targeted depths and locations) were critical in the assessment of this site
• Always specify continuous, full 2-foot penetrations for soil borings and retain the entire sample recovered
Case Study # 3 – Infiltration Gallery

Preconstruction: two double-ring tests in same pit

- Test 1
  - Depth = 9 feet
  - Soil = Silty Sand
  - P200 = 28%
  - KC Calc = 3.1 in/hr
  - DR Rate = 3.6 in/hr

- Test 2
  - Depth = 11 feet
  - Soil = Sand
  - P200 = 1.4%
  - KC Calc = 28.3 in/hr
  - DR Rate = 32.4 in/hr

Recommendations
- Max. Design Rate = 8 in/hr
- Correction Factor > 3.5
- Remove and replace silty sand
- Test pits during construction to look for layering

Design
- Reduced system footprint about 65%
- Smaller system set outside of test pit area, but still in area with boring data
Case Study # 3 – Infiltration Gallery

• During Construction: four double-ring tests at design base
  – Test 1: 1.3 in/hr (6.4% P200)
  – Test 2: 0 in/hr* (4.3% P200)
  – Test 3: 0 in/hr* (5.6% P200)
  – Test 4: 0 in/hr*

*Test stopped at 60 min or less

• Where’s The Flow? (WTF)
Case Study # 3 – Infiltration Gallery

• X-Ray Diffractometer: Expansive Clay

“The major clay mineral (S = 15Å peak) swelled when treated with ethylene glycol vapor and this is indicative of a smectite clay mineral (similar to a montmorillonite or a beidellite – common to bentonite).”

Dr. Scott Schlorholtz, Iowa State University, 5/16/2011
Case Study # 3 – Infiltration Gallery

1 Day

14 Days

28 Days

48 Days
Take Home Points:

• “One test is worth a thousand opinions.”
  – Terrence E. Swor, P.G.
• Consult available soil references first, but consider the source
• Sample the full soil profile
• Sample where you plan to infiltrate
• Follow up with infiltration field testing, especially if “failure is not an option.”
The Difference a Clay Makes

Mottling due to past trapping of water above

The restrictive layer 1” of impervious soil
Thank you for the opportunity to speak with you today.

Further Questions? Please contact me.

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