Stormwater Management Studies in Areas Undergoing Reconstruction Following the Tornado that Hit Tuscaloosa, AL

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Introduction

- The performance of bioinfiltration facilities and other infiltration devices can be affected by factors such as texture, structure and degree of compaction of the media used during construction and the underlying soils.
- Large borehole infiltration tests were conducted in the Tuscaloosa area to compare with small surface infiltration measurements.
- Controlled laboratory column tests were conducted to examine the effects of different compaction levels on the infiltration rates through the soil media obtained from the surface and subsurface of bioinfiltration test sites, along with benefits associated with mixing sand with the media mixture.

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Soil Media Characteristics of Proposed Stormwater Bioinfiltration Construction Sites

Laboratory and field-scale studies were conducted to provide information of the existing soil in areas which were severely affected by the April 27, 2011 tornado that devastated the city of Tuscaloosa, AL, and are undergoing reconstruction.

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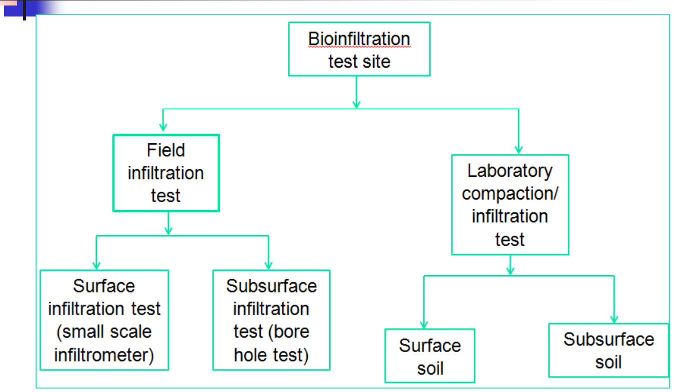
Bioinfiltration Site and Lab Infiltration Studies



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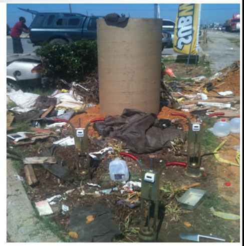
Field Surface and Subsurface Infiltration Tests

- Surface double-ring infiltration tests and large bore hole infiltration measurements were conducted to determine the surface and subsurface infiltration characteristics.



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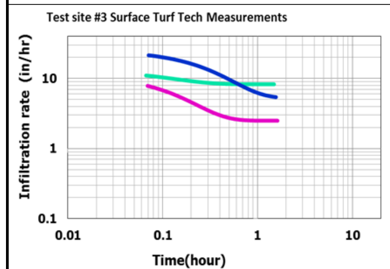
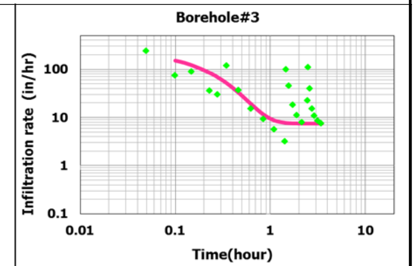
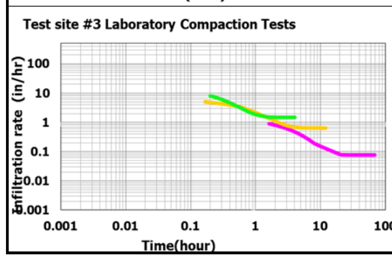
Example of Surface Tuft Tech, Borehole , and Lab Infiltration Data Fitted to Horton's Equation.







Test methods resulted in varying results; in this case, the soil at the bottom of the borehole was little compacted and had higher infiltration rates than the surface soil.

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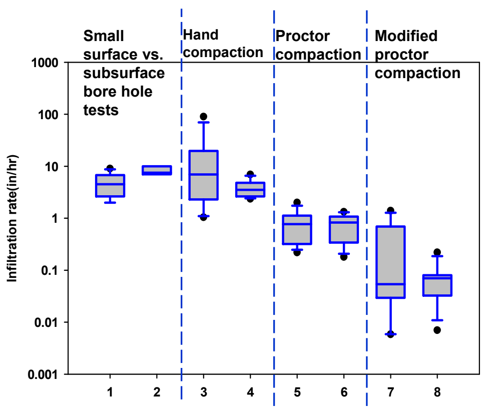
Summary of Surface, Subsurface, and Lab Infiltration Data for the Proposed Bioinfiltration Sites

Box and whisker plots comparing saturated soil infiltration rates (in/hr). Test series descriptions (12 replicates in each test series except for the borehole tests which only included 3 observations):

1. Tur-Tec small double ring infiltrometer
2. Pilot-scale borehole infiltration tests
3. Surface soil composite sample with hand compaction
4. Subsurface soil composite sample with hand compaction
5. Surface soil composite sample with standard proctor compaction
6. Subsurface soil composite sample with standard proctor compaction
7. Surface soil composite sample with modified proctor compaction
8. Subsurface soil composite sample with modified proctor compaction



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Summary of *In-situ* Soil Density Measurements at the Proposed Bioinfiltration Sites

Location	Horton's parameter f_o(in/hr) mean	f_c(in/hr) mean	k(1/min) mean	Dry density (g/cc)
Test site #1	10	4	0.15	1.88
Test site #2	7.2	4	0.12	1.66
Test site #3	16.5	5.3	0.10	1.61
Test site #4	24	7	0.06	1.66

General relationship of soil bulk density to root growth on soil texture (USDA Natural Resources Conservation Service)

Soil Texture	Ideal bulk densities for plant growth (g/cm^3)	Bulk densities that restrict toot growth (g/cm^3)
Sandy	<1.60	>1.80
Silty	<1.40	>1.65
Clayey	<1.10	>1.47

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Laboratory Column Tests

- Three levels of compaction were used to modify the density of the media layer during the tests: hand compaction, standard proctor compaction, and modified proctor compaction.
- Four-inch (100 mm) diameter PVC pipes 3 ft (0.9 m) long, were used for these tests

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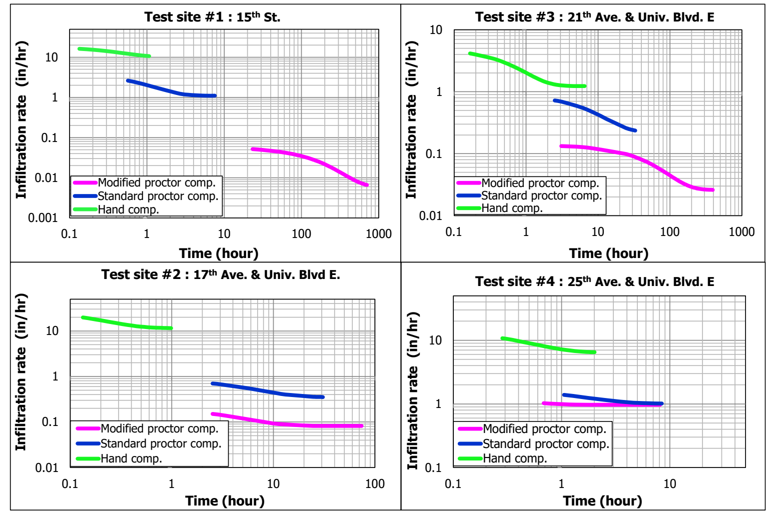
Summary of Lab Surface Soil Infiltration Test Data Fitted to Horton's Equation.



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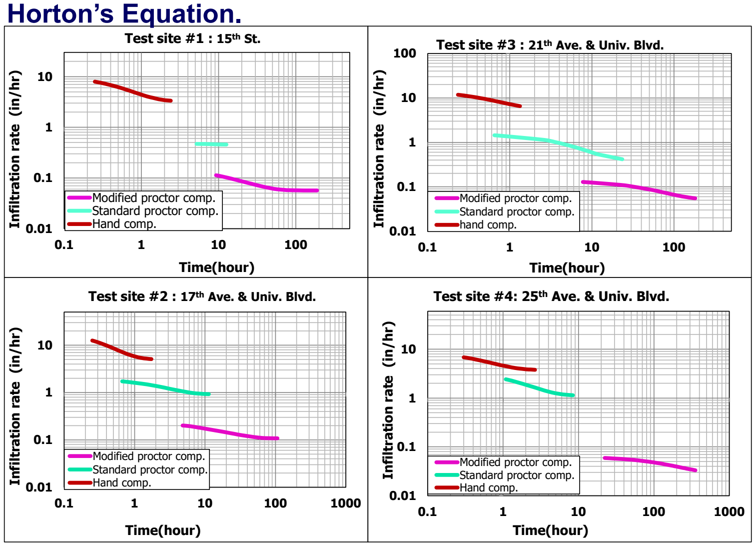
Summary of Lab Subsurface Soil Infiltration Data Fitted to Horton's Equation.



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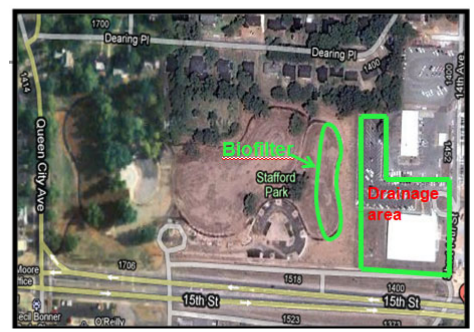
Field and Lab Studies at Existing Poorly-functioning Biofilter

- The biofilter facility is located in Shelby Park, adjacent to The Univ. of Alabama rental car parking lot from which it receives flow.
- The biofilter is about 300 ft long and 30 ft wide (0.21 acres) and is about 11% of the paved and roofed source area.



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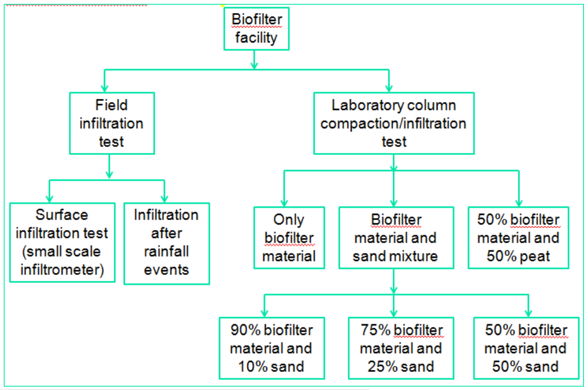
Field and Lab Infiltration Study of Poorly Functioning Biofilter Facility



Field Infiltration Tests

- Four clusters of three Turf-Tec infiltrometer tests were conducted along the biofilter to examine variations along the biofilter length.
- The biofilter media was classified as sandy clay loam, with 20% clay and 80% sand (3% organic matter content).

Very little "bio" in this biofilter, indicating compacted media having adverse affects on plant growth.

In-situ Density Measurements of Biofilter Media

- A small hole about 6 in. deep and 6 in. wide was hand dug and the soil brought to the lab for analyses.
- Sand was then poured into the hole from a graduated cylinder to measure the volume of the excavation.
- The moisture, mass, texture, and the density of the excavated media were determined.

Summary of *In-situ* Soil Density Measurements

Shelby Park biofilter media characteristics (sandy clay loam)

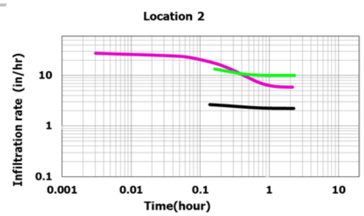
Test locations	Median size D_{50} (mm)	Uniformity coefficient (C_u)	Bulk density (g/cm³)
1	3	37.5	2.18
2	0.5	17	2.32
3	0.32	5.56	1.8
4	0.73	n/a	2.05

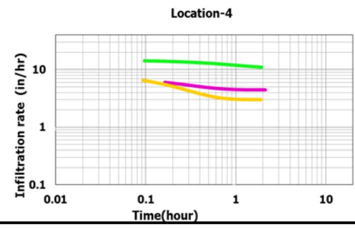
General relationship of soil bulk density to root growth on soil texture (USDA Natural Resources Conservation Service)

Soil Texture	Ideal bulk densities for plant growth (g/cm³)	Bulk densities that restrict toot growth (g/cm³)
Sandy	<1.60	>1.80
Silty	<1.40	>1.65
Clayey	<1.10	>1.47

Field Infiltration Test Results

- The average initial infiltration rates during the Turf Tec field tests were about 11 in/hr (280 mm/hr), and ranged from 3 to 28 in/hr (75 to 710 mm/hr).
- The final rates had an average value of about 4.6 in/hr (115 mm/hr), and ranged from 1.5 to 10.5 in/hr (38 to 270 mm/hr), indicating non-compacted surface soils.





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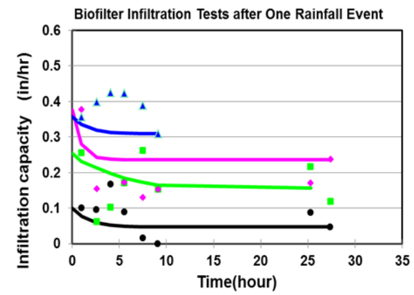
Infiltration after Rainfall Events



These very low values were about equal to the observed laboratory tests conducted under the most severe compaction conditions (the modified proctor compaction tests).

Extended ponding of water in low area of biofilter after rain.

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Laboratory Column Tests

- The effects of different compaction levels on infiltration rates, along with benefits associated with adding sand to the media mixture, were examined with column tests.

Shelby Park biofilter media			
Compaction	f_o (in/hr)	f_c (in/hr)	K (1/min)
Modified Proctor Compaction; density 1.96 g/cc	0.39	0.26	0.001
Standard Proctor Compaction; density 1.66 g/cc	0.99	0.81	0.010
Hand Compaction; density 1.54 g/cc	6.20	4.09	0.0363

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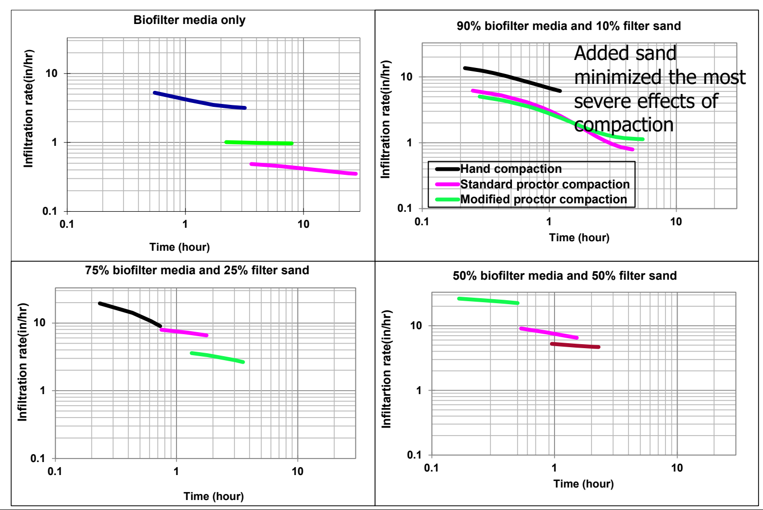
Summary of Field and Lab. Infiltration Data Fitted to Horton's Equation



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Lab Column Tests for Predicting Changes in Flow with Changes in Various Biofilter Mixtures

- A series of controlled lab column tests conducted using various mixtures of sand and peat to predict changes in flow with changes in the mixture, focusing on media density associated with compaction, particle size distribution (and uniformity), and amount of organic material.
- The results of the predicted performance of these mixtures were also verified using column tests (for different compaction conditions) of surface and subsurface soil samples obtained from Tuscaloosa, AL, infiltration test areas, along with bioretention media obtained from actual Kansas City biofilters and standard samples of North Carolina biofilter media.

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Full 2^4 Factorial Design

Case	Texture	Uniformity	Organic content	Compaction	Average Fc for test conditions (cm/hr)
1	+	+	+	+	9.1
2	+	+	+	-	20.9
3	+	+	-	+	5.2
4	+	+	-	-	5.8
5	+	-	+	+	110
6	+	-	+	-	282
7	+	-	-	+	1,000
8	+	-	-	-	1,030
9	-	+	+	+	6.7
10	-	+	+	-	46.4
11	-	+	-	+	2.8
12	-	+	-	-	15.8
13	-	-	+	+	7.1
14	-	-	+	-	41.9
15	-	-	-	+	5.5
16	-	-	-	-	8.1

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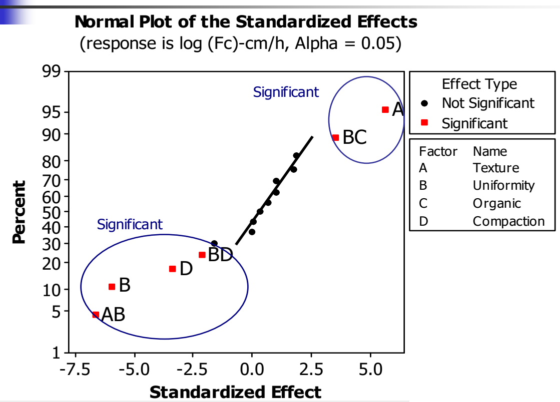
Probability Plot for Different Factors



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Conclusions

- Small-scale infiltrometers work well if surface characteristics are of the greatest interest. Large-scale (deep) infiltration tests would be appropriate when subsurface conditions are of importance (as in bioinfiltration systems and deep rain gardens).
- Soil compaction has dramatic effects on the infiltration rates; therefore care needs to be taken during stormwater treatment facilities construction to reduce detrimental compaction effects.
- The lab compaction tests using various mixtures of sand and peat indicated that median particle size and media particle uniformity have the most significant effects on the infiltration rates; while compaction and the amounts of organic material had a smaller effect.

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