Infiltration Through Compacted Urban Soils and Effects on Biofiltration

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Abstract

- Previous research identified significant reductions in infiltration rates in disturbed urban soils.
- More than 150 prior tests were conducted in predominately sandy and clayey urban soils in the Birmingham and Mobile, Alabama, areas.
- Infiltration in clayey soils was found to be affected by an interaction of soil moisture and compaction, while infiltration in sandy soils was affected by soil compaction alone.

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Applications of These Data

- Newer tests were conducted under more controlled laboratory conditions and represent a wider range of soil textures and specific soil density values.
- The high head conditions during these tests make these results suitable for biofiltration/infiltration devices that have 1 to 2 ft of head, but are likely too high for normal infiltration rates through urban soils.

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Disturbed Urban Soils during Land Development

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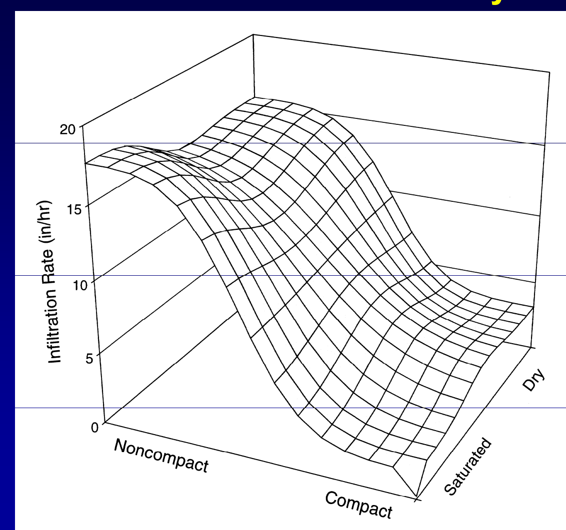
Infiltration Rates in Disturbed Sandy Urban Soils



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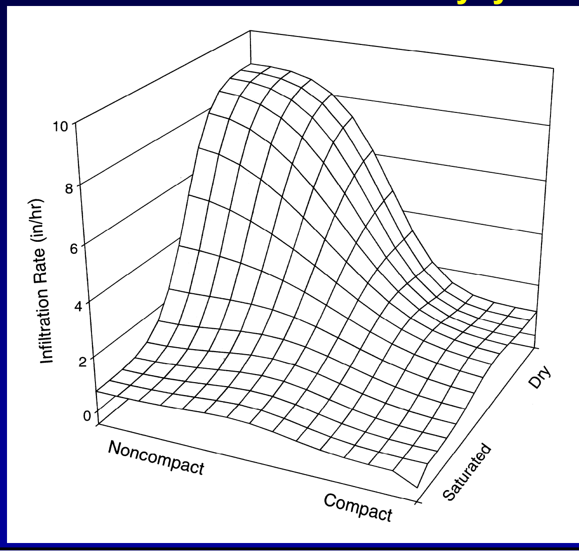
Infiltration Rates in Disturbed Clayey Urban Soils



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Infiltration Rates during Prior Tests of Disturbed Urban Soils

	Number of tests	Average infiltration rate (in/hr)	COV
Noncompacted sandy soils	36	13	0.4
Compacted sandy soils	39	1.4	1.3
Noncompacted and dry clayey soils	18	9.8	1.5
All other clayey soils (compacted and dry, plus all wetter conditions)	60	0.2	2.4

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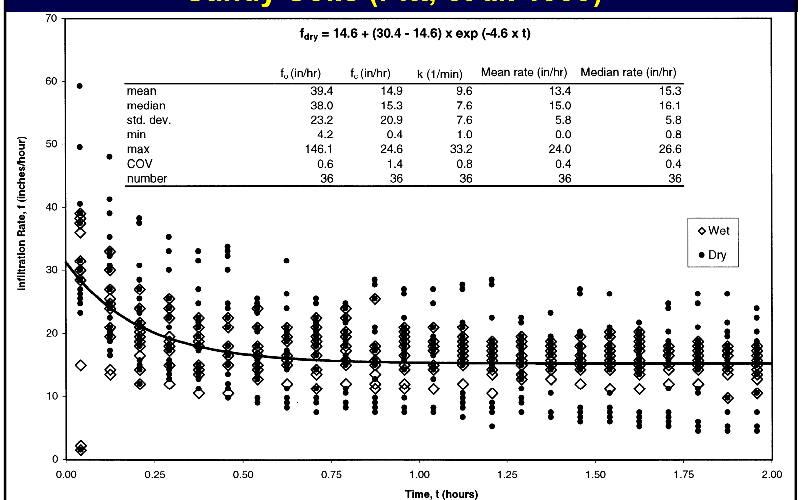
Infiltration Measurements for Noncompacted, Sandy Soils (Pitt, *et al.* 1999)



	f_o (in/hr)	f_c (in/hr)	k (1/min)	Mean rate (in/hr)	Median rate (in/hr)
mean	39.4	14.9	9.6	13.4	15.3
median	38.0	15.3	7.6	15.0	16.1
std. dev.	23.2	20.9	7.6	5.8	5.8
min	4.2	0.4	1.0	0.0	0.8
max	146.1	24.6	33.2	24.0	26.6
COV	0.6	1.4	0.8	0.4	0.4
number	36	36	36	36	36

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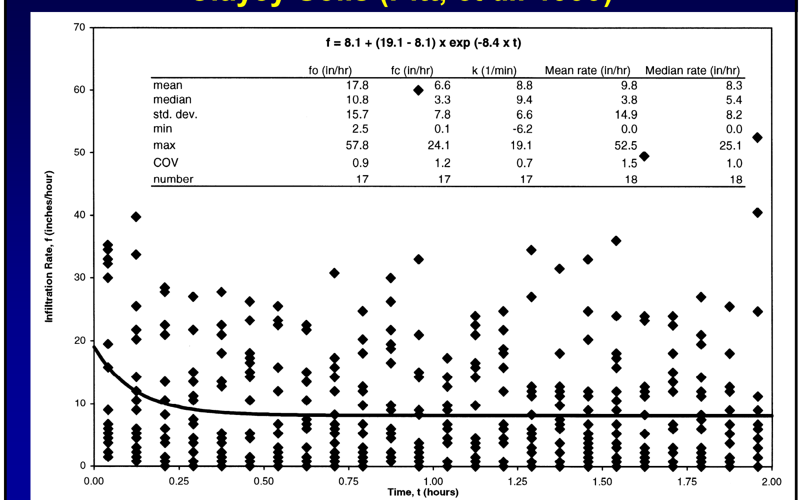
Infiltration Measurements for Dry-Noncompacted, Clayey Soils (Pitt, *et al.* 1999)



	fo (in/hr)	fc (in/hr)	k (1/min)	Mean rate (in/hr)	Median rate (in/hr)
mean	17.8	6.6	8.8	9.8	8.3
median	10.8	3.3	9.4	3.8	5.4
std. dev.	15.7	7.8	6.6	14.9	8.2
min	2.5	0.1	-6.2	0.0	0.0
max	57.8	24.1	19.1	52.5	25.1
COV	0.9	1.2	0.7	1.5	1.0
number	17	17	17	18	18

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Method

- These newer tests were run for up to 20 days, although most were completed (when steady low rates were observed) within 3 or 4 days.
- Initial soil moisture levels were about 8% (sand was about 3%), while the moisture levels after the tests ranged from about 20 to 45%.
- Three methods were used to compact the test specimens: hand compaction, plus two Proctor test methods.
- Both Modified and Standard Proctor Compactions follow ASTM standard (D 1140-54).

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Method (cont.)

- Hand compaction (gentle hand pressing to force the soil into the mold with as little compaction as possible),
- Standard Proctor Compaction (24.4 kN hammer dropped 25 times form 300 mm on each of 3 soil layers).
- Modified Proctor Compaction (44.5 kN hammer dropped 25 times from 460 mm on each of 5 soil layers).

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Method (cont.)

- A total of 7 soil texture types were tested representing all main areas of the standard soil texture triangle.
- Three levels of compaction were tested for each soil.
- Only 15 tests resulted in observed infiltration. The Standard and Modified Proctor clay tests, the Modified Proctor clay loam, and all of the clay mixture tests did not result in any infiltration, even after several days.

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Test Mixtures for Laboratory Tests

	Sand	Clay	Silt	Sandy loam	Clayey loam	Silty loam	Clay mix
% sand	100			72.1	30.1	19.4	30
% clay		100		9.2	30.0	9.7	50
% silt			100	18.7	39.9	70.9	20

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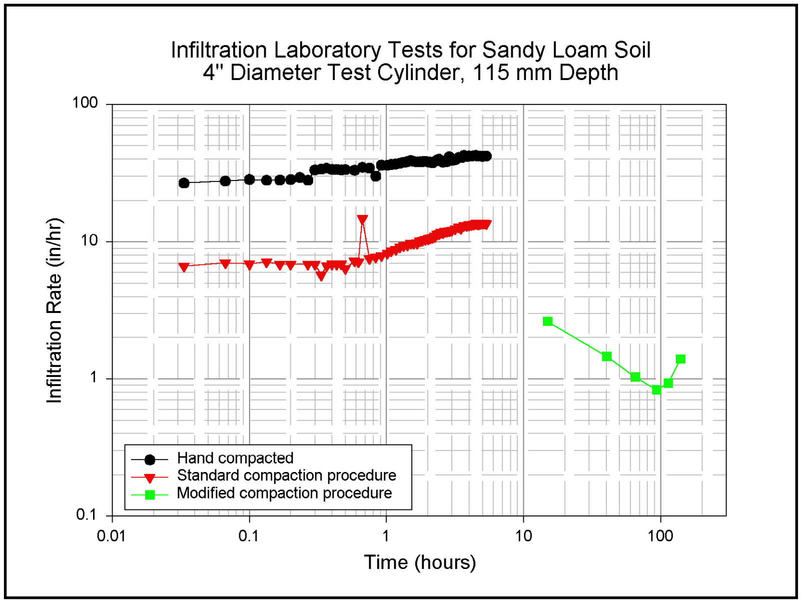
Infiltration Laboratory Tests for Sandy Loam Soil
4" Diameter Test Cylinder, 115 mm Depth
Infiltration Rate (in/hr)
Time (hours)
100
10
1
0.1
0.01
0.1
1
10
100
Hand compacted
Standard compaction procedure
Modified compaction procedure

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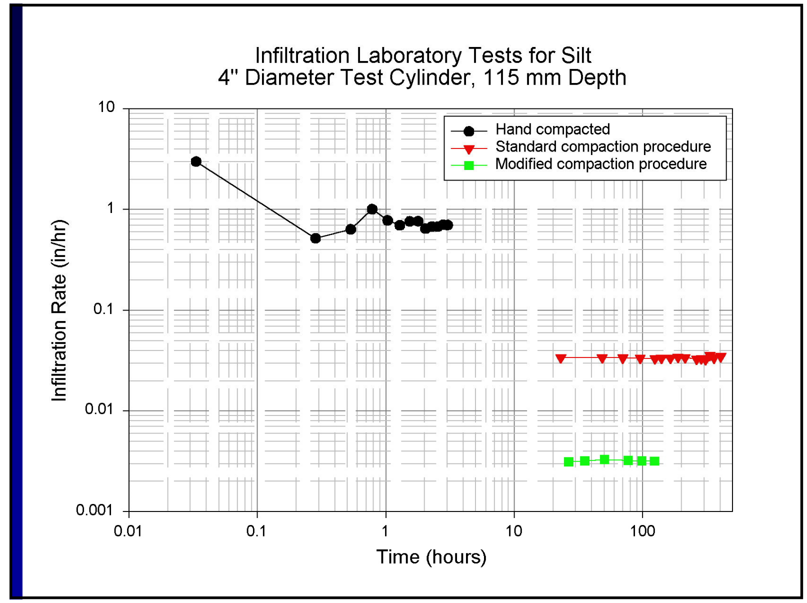
Infiltration Laboratory Tests for Silt
4" Diameter Test Cylinder, 115 mm Depth
Infiltration Rate (in/hr)
Time (hours)
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100
Hand compacted
Standard compaction procedure
Modified compaction procedure

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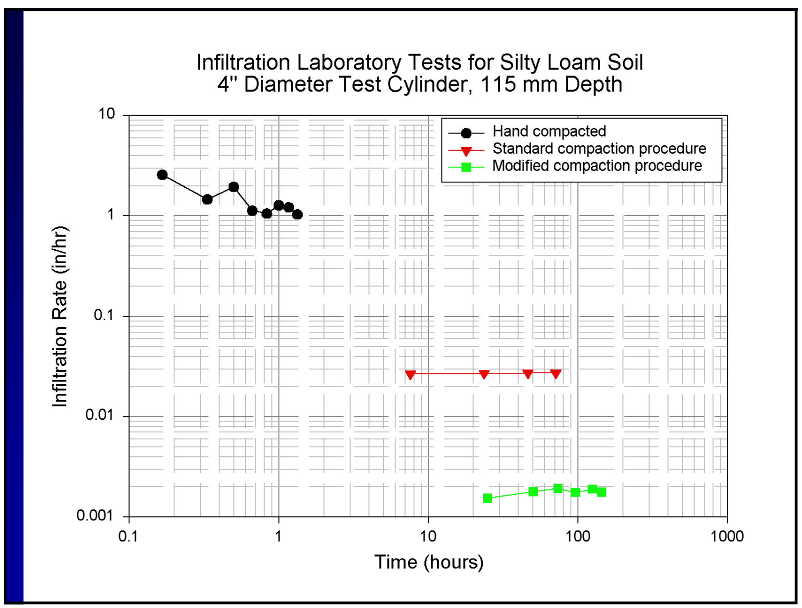
Infiltration Laboratory Tests for Silty Loam Soil
4" Diameter Test Cylinder, 115 mm Depth
Infiltration Rate (in/hr)
Time (hours)
10
1
0.1
0.01
0.001
0.1
1
10
100
1000
Hand compacted
Standard compaction procedure
Modified compaction procedure

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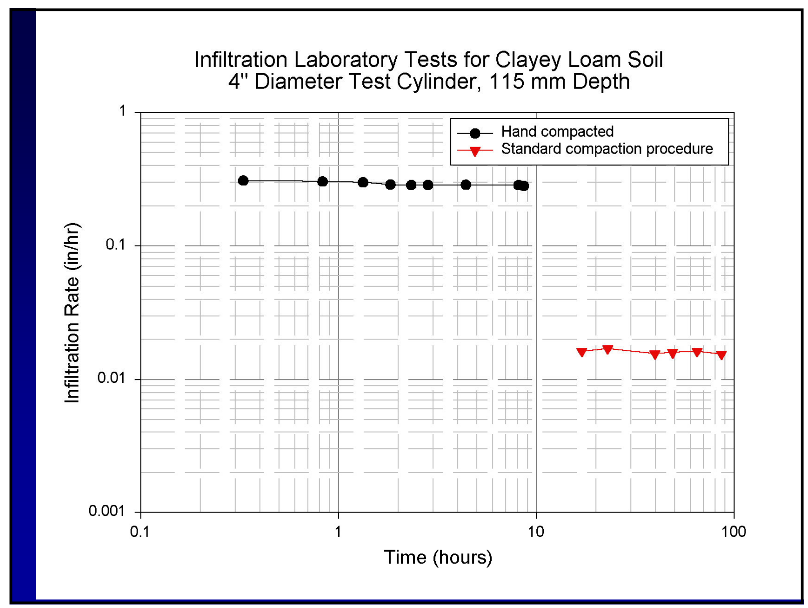
Infiltration Laboratory Tests for Clayey Loam Soil
4" Diameter Test Cylinder, 115 mm Depth
Infiltration Rate (in/hr)
Time (hours)
1
0.1
0.01
0.001
0.1
1
10
100
Hand compacted
Standard compaction procedure

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Long-Term Sustainable Average Infiltration Rates

Soil Texture	Compaction Method	Dry Bulk Density (g/cc)	Effects on Root Growth (per NRCS)	Long-term Average Infilt. Rate (in/hr)
Silt	Hand	1.508	May affect	0.7
	Standard	1.680	May affect +	0.034
	Modified	1.740	Restrict	0.0030
Sand	Hand	1.451	Ideal	Very high
	Standard	1.494	Ideal	0.5 ?
	Modified	1.620	May affect -	3.2
Clay	Hand	1.241	May affect	0.12
	Standard	n/a	n/a	0
	Modified	n/a	n/a	0

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Long-Term Sustainable Average Infiltration Rates (cont.)

Soil Texture	Compaction Method	Dry Bulk Density (g/cc)	Effects on Root Growth (per NRCS)	Long-term Average Infilt. Rate (in/hr)
Sandy Loam	Hand	1.595	May Affect	35
	Standard	1.653	May Affect	9
	Modified	1.992	Restrict	1.5
Silt Loam	Hand	1.504	May Affect	1.3
	Standard	1.593	May Affect	0.027
	Modified	1.690	May Affect +	0.0017
Clay Loam	Hand	1.502	May Affect	0.29
	Standard	1.703	Restrict	0.015
	Modified	1.911	Restrict	0

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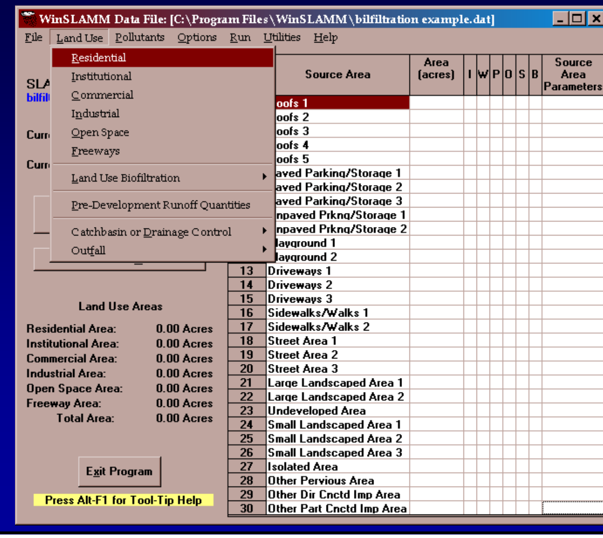
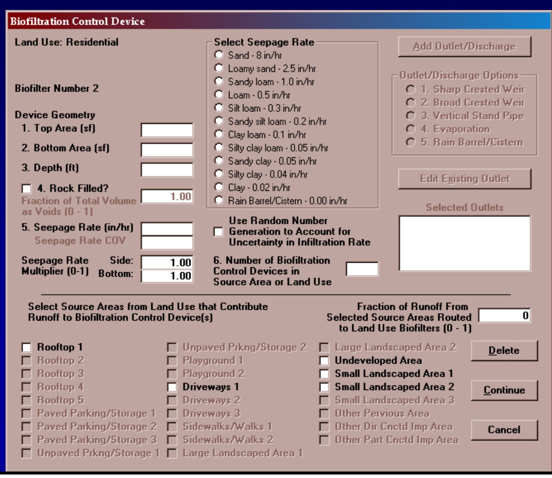
The Source Loading and Management Model (SLAMM)

- Developed during past 25 years during EPA, state, and Canadian funded research.
- Identifies pollutant sources during different rain and climatic conditions.
- Prioritizes subwatersheds and critical source areas.
- Evaluates alternative development scenarios, pollution prevention, and combinations of source area and outfall control options.

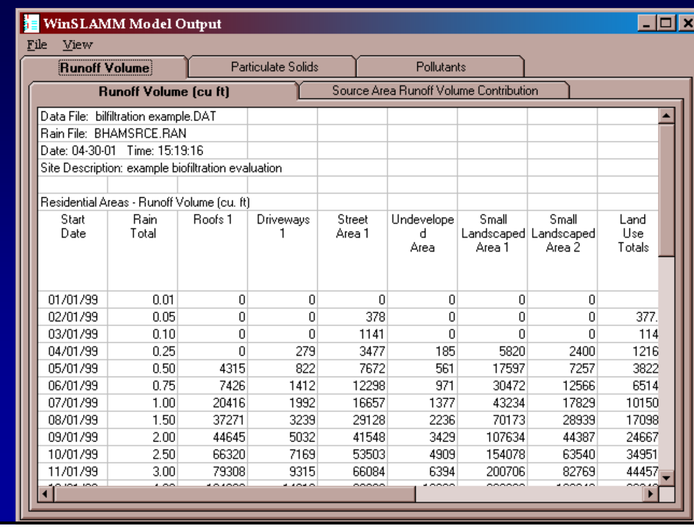
Example SLAMM Land Use Screen

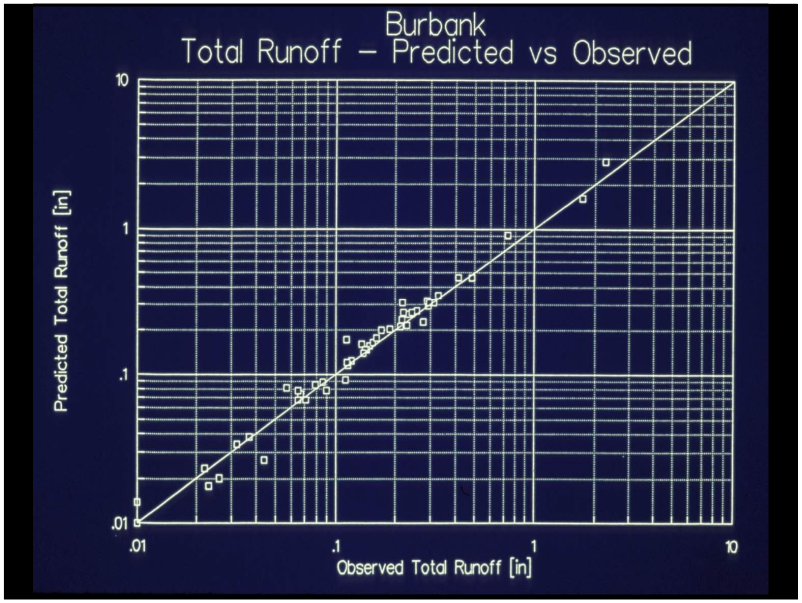


Example SLAMM Data Input Screen for Biofiltration Controls



Example SLAMM Output Screen




Burbank
Total Runoff – Predicted vs Observed
Predicted Total Runoff [in]
Observed Total Runoff [in]
10
1
.1
.01
.01
.1
1
10

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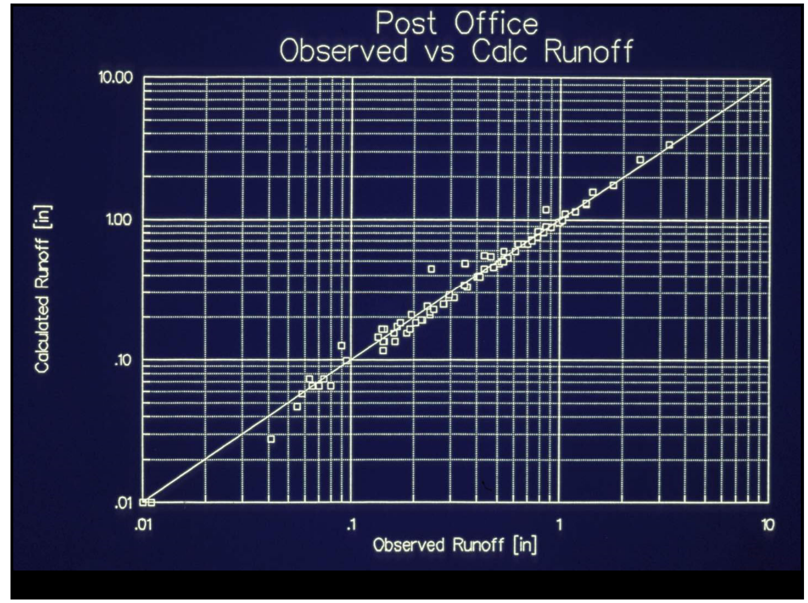
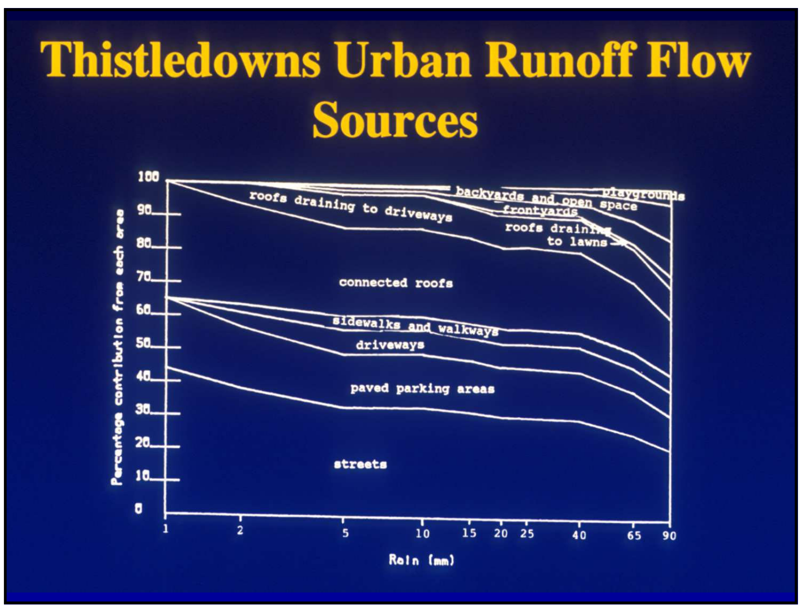

Post Office
Observed vs Calc Runoff
Calculated Runoff [in]
Observed Runoff [in]
10.00
1.00
.10
.01
.01
.1
1
10

30


Thistledowns Urban Runoff Flow Sources
Percentage contribution from each area
Rain (mm)
backyards and open space
playgrounds
frontyards
roofs draining to driveways
roofs draining to lawns
connected roofs
sidewalks and walkways
driveways
paved parking areas
streets
100
90
80
70
60
50
40
30
20
10
0
1
2
5
10
15
20
25
40
65
90

31

32

33

34

35

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Conclusions

- These tests indicated that both texture and compaction were important in determining the infiltration rates, with time since the beginning of rain only important for less than half of the conditions tested.
- These tests were conducted using a 1.1 m head and are most appropriate for biofiltration and infiltration designs where ponded water may occur. A series of tests were also conducted for sandy loam using 0.1 m head and the resulting infiltration rates were substantially less.

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Conclusions (cont.)

- These results (and those from the previous tests), however, do indicate significant effects associated with soil compaction. The prior field tests of infiltration rates for disturbed urban soils provided basic rates (and COV values) that are recommended for typical urban hydrology studies.
- SLAMM can be used to quantify the benefits of alternative soil structures and modifications on infiltration and biofiltration options.

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Acknowledgements

Our earlier disturbed soil tests are described in the following EPA research report. Funding for this initial work was provided by the EPA and is gratefully acknowledged. The recent tests reported in this poster were conducted as an individual research project by C.K. Ong, a soil engineering student at UAB, under the direction of Dr. Shen-en Chen. Their dedicated help is greatly appreciated.

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References

Pitt, R., J. Lantrip, R. Harrison, C. Henry, and D. Hue. *Infiltration through Disturbed Urban Soils and Compost-Amended Soil Effects on Runoff Quality and Quantity*. U.S. Environmental Protection Agency, Water Supply and Water Resources Division, National Risk Management Research Laboratory. EPA 600/R-00/016. Cincinnati, Ohio. 231 pgs. December 1999.

NRCS. Soil Quality Institute 2000, Urban Technical Note 2, as reported by Ocean County Soil Conservation District, Forked River, NJ. 2001.