Infiltration rates associated with green space loss and compaction due to urbanization

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Abstract:

In recent years urbanization in Burlington has led to increased green space loss. With a continual rise in population, the demand for driveways and parking lots multiplies. With a loss of vegetation and an increase of compacted areas due to further urbanization, less water is infiltrated. Our studies found that in a compacted driveway the infiltration rate is 8.17 cm/hour. In comparison to thick grass, which has an infiltration rate of 21.5cm/hour. Since Burlington is situated on a hill, run off can become a problem. The run off carries surface contaminants such as car oil to Lake Champlain. Greater amounts of sediment are relocated to unwanted areas. For example, the sediment can create blockage within storm drains. This is a common problem in urban areas; however, it is not made known to the public. This study clearly proves that the loss of vegetation has a negative affect on water control. The only way in which this problem can be remedied is through widespread presentation of our findings.

Introduction:

Throughout time, society has continually altered the environment, transforming rural areas into urbanized ones. This transformation has had an extreme impact on the land phase of the hydrologic cycle. (Urban Hydrology, 1984) In response to this increased impact on hydrology people have constructed storm sewers and realigned natural stream channels. As result of these altercations, water is transmitted into the drainage network at a faster rate. This in turn leads to an increase in flow velocities. These results are all integrally related to varying infiltration rates on particular surface areas. (Urban Hydrology, 1984)

The study performed by Paul Melillo, Richard Morse, and Heidi Keller was conducted to reveal the difference in infiltration rates on urbanized surfaces: including lawns, driveways, yards, and informal parking areas. The objective was to determine how much water infiltrates in relationship to the amount of precipitation that occurs. Different surfaces will have different levels of permeability and porosity and therefore, different infiltration rates

Methods and Materials:

Set up

The study was done at varying locations. At each location a specific area was tested. A catchment was constructed with an approximate area of 6,125 cm^2. A tear shaped ridged structure made of tin encompassed the plot in order to standardize the area. The structure was placed on a surface with a slight grade. The tin wall provided a method of control for the direction of the water running off. To ensure that water would not escape from our plots', plaster was applied around the inner edges of the wall that would come in contact with the most water. Plaster was applied on the mouth of the catchment plot as well. The plaster applied at the mouth of the plot made it easier for the water to run off and not get caught within the soil. The outer edges of the plot were compacted with soil. At the mouth of the structure, which was the lowest point of the plot, a hole was dug. Buckets were placed in the hole to collect the run off.

Within the plot we placed three rain gauges equidistant from one another to collect the precipitation. In order to stimulate rain, 4-gallon backpack sprayers were used. Water was sprayed uniformly over the plot using these sprayers. The water was caught in the precipitation collectors and eventually in the buckets as water ran off.

Procedure

After the plot was constructed, we placed our first collection bucket in the hole (bucket #1), started the timer, and began spraying uniformly over the area. As soon as run off was detected, the time was noted and the precipitation collectors were read. The bucket was not changed until after it had been filled with run off water. Once bucket #1 filled up we noted the time, the amount of water in the precipitation collectors, and removed the bucket. It was replaced with bucket #2. For most experiments, we continued this procedure using between ten to eleven buckets. After each bucket was removed from the hole, the amount of water in the bucket was measured in ml. Either one or two sprayers were used on the plot depending upon the infiltration rate. The plot sited on grass needed two sprayers working together, while the paved surfaces only required one sprayer. With the measured amount of run off, the amount of precipitation collected, and the noted time intervals we were able to calculate the infiltration rate for each surface.

Trial 2 Informal Parking

TABLE # 1 COLLECTED DATA

BUCKET #	TIME (minutes, seconds)		RAIN COLLECTORS (cm) 1	2	3	INTERVAL (cm)
1	0	0	0	0	0	0
2	3	0	0.4	0.4	0.6	0.53
3	6	30	1	0.8	1.2	0.47
4	9	30	1.4	1.4	1.6	0.33
5	11	30	1.6	2	1.8	0.33
6	14	0	1.8	2.6	2	0.37
7	16	30	2.2	3.1	2.2	0.47
8	19	0	2.4	3.9	2.6	0.5
9	21	30	2.8	4.4	3.2	0.43
10	23	40	3.2	4.8	3.7	

	RAIN RATE (cm / hr)	RUNOFF (ml)	RUNOFF (cm)	INFILTRATION (cm/hr)
	0	0	0	0
	9.1	700	0.11	9
	11.2	750	0.12	11.1
	8	750	0.12	7.9
	8	750	0.12	7.9
	8.8	800	0.13	8.7
	11.2	750	0.12	11.1
	12	775	0.125	11.9
	12	850	0.14	11.9
AVERAGE				8.9

CALCULATIONS:

Runoff (ml) / Area = 700 / 6125 = Runoff (cm) 0.11

Rain Rate (cm/hr) 9.1 - Runoff (cm) 0.11 = Infiltration (cm/hr) 9

This is a representative data table, illustrating how the data was recorded. A chart was made for each trial. We had five plots, all but the thick grass plot was experimented on twice.

Discussion:

Our results suggest that the amount of traffic on an area causes less water to be absorbed and as a result, there is a greater percentage of water on the surface. When a rainstorm occurs, the rain is intercepted by vegetation, and then hits the ground. At this point it begins to fill the depressions within the particular surface. Soil characteristics such as: the size of the pore spaces and the degree of compaction will influence the amount of water being absorbed. The remaining water that is not absorbed into the soil and plants becomes run off.(Water, Earth and Man, 1969)

As compaction increases, the infiltration rate decreases. The role of vegetation is very important in controlling infiltration and run off. When we experimented on thick grass, we produced our maximum amount of rain for the longest period of time. Despite the amount of water used on the area there wasn't any run off and there was 100% infiltration. The amount of time and rain was 75% less on the heavily compacted driveway then it was on thick grass. The amount of water infiltrated on the compacted driveway was the lowest of the plots we observed; as a result, the run off was the highest. (Table 1)

Increases in population lead to more drive ways, parking lots, and other such compacted surfaces that produce water run off. As the infiltration rate decreases the rate of water run off will increase, creating future problems such as: flooding and contamination of water. As urbanization increases, green space is lost and the increase in the amount of water in the sewer systems becomes a threat to the community. Sewer systems are only designed to hold a specific amount of water. Through green space loss the sewer containment capacity is exceeded. For pavement or paved areas the infiltration rate is little to none (Bierman, 2001). For heavily compacted driveway surfaces the infiltration rate is 8.17 cm/hour; however, in areas of thick grass (lawns) it is 21.5cm/hour.

Limiting factors such as surface gradient, soil pore spaces, vegetation and compaction have noticeable affects on infiltration. When there is a low surface gradient, gravity has less of an effect on the movement of water. On flat surfaces water has more time to infiltrate because it is not being carried away by the potential gradient of the ground.(Journal of Environmental Quality, 1999) The affinity of the soil particles, whether they are clay, silt, or sand, is directly related to the rate at which the soil absorbs water. Increased absorption is also caused by plant roots. They create more pore spaces allowing water to be absorbed faster. When soil is highly compacted there is little or no space in the soil below for the water to permeate. (Water Earth and Man, 1969.) When societies urbanize rural lands green space is lost and/or compacted. The results indicated that as compaction increases and vegetation decreases, there is a greater probability of water that enters the storm sewers.

Summary

In our experiment the run off was collected in buckets. We noted how much time it took to collect an entire bucket of water. The amount of time coupled with the amount of water gave us the data to determine how much rain was collected per/hour. By using the precipitation collectors we were able to see how much rain was distributed over our plot. The average distribution of rain subtracted from the run off per/hour gave us infiltration rates in cm/hour.

When comparing the five plots we were able determine trends among different plots. The informal parking plot had the lowest rain fall rate of 5.6 cm/hour. Despite the fact that there was little rain on the area, run off started after only 150 seconds. In all the plots the soil had a sandy consistency. Sand absorbs water very well; however, in the heavily compacted driveway infiltration was 6.53 cm/hour, extremely low. The thick grass plot had the steepest slope of 0.1. Although the plot had the highest gradient, the infiltration was still the highest at 21.5cm/hour. This plot was also rained on for the greatest amount of time; six thousand nine hundred seconds. The extended rain fall proves that vegetation is an important factor pertaining to water absorption.

For a final analysis infiltration rates of the plots were compared to total time. Interestingly enough the informal parking plot had equal infiltration rates. The second trial on the informal parking was previously rained on during the first trial. This did not affect infiltration. For the lawn plots the infiltration of the second trial was greater. Despite the fact that it still water on it from the first trial, the infiltration rate increased. Our final data shows that infiltration rate decreases as vegetation is lost: thick grass, lawn, informal parking, partial driveway, heavily compacted driveway. This supports the idea that the loss of green space due to urbanization causes lower infiltration rates.

References

1. Chorly, Richard. Water, Earth, and Man. Methuen & Co Ltd. Great Britain: 1969.

2. Hall, M.J. Urban Hydrology. Elsavier Applied Science Publishers. New York: 1984.

3. Wahlstrom, Erick. (1999) Hydrologic response. Journal of Environmental Quality, 14,no.1, 481-492.

4. Weyman, Darrell. Runoff Processes and Stream Flow Modeling. Oxford University Press. London: 1975.

5. Yangwen, Jia. (2001.) Simulation of Hydrologic cycle in an Urbanized Watershed and Effect of Infiltration Facilities with WEP Model. Journal of Hydroscience and Hydraulic Engineering, 19, no.1, 43-52.

6. Paul Bierman, Department of Geology. University of Vermont, Verbal communication, 2001.

7. Paul Melillo. Senior, University of Vermont, data, 2001.

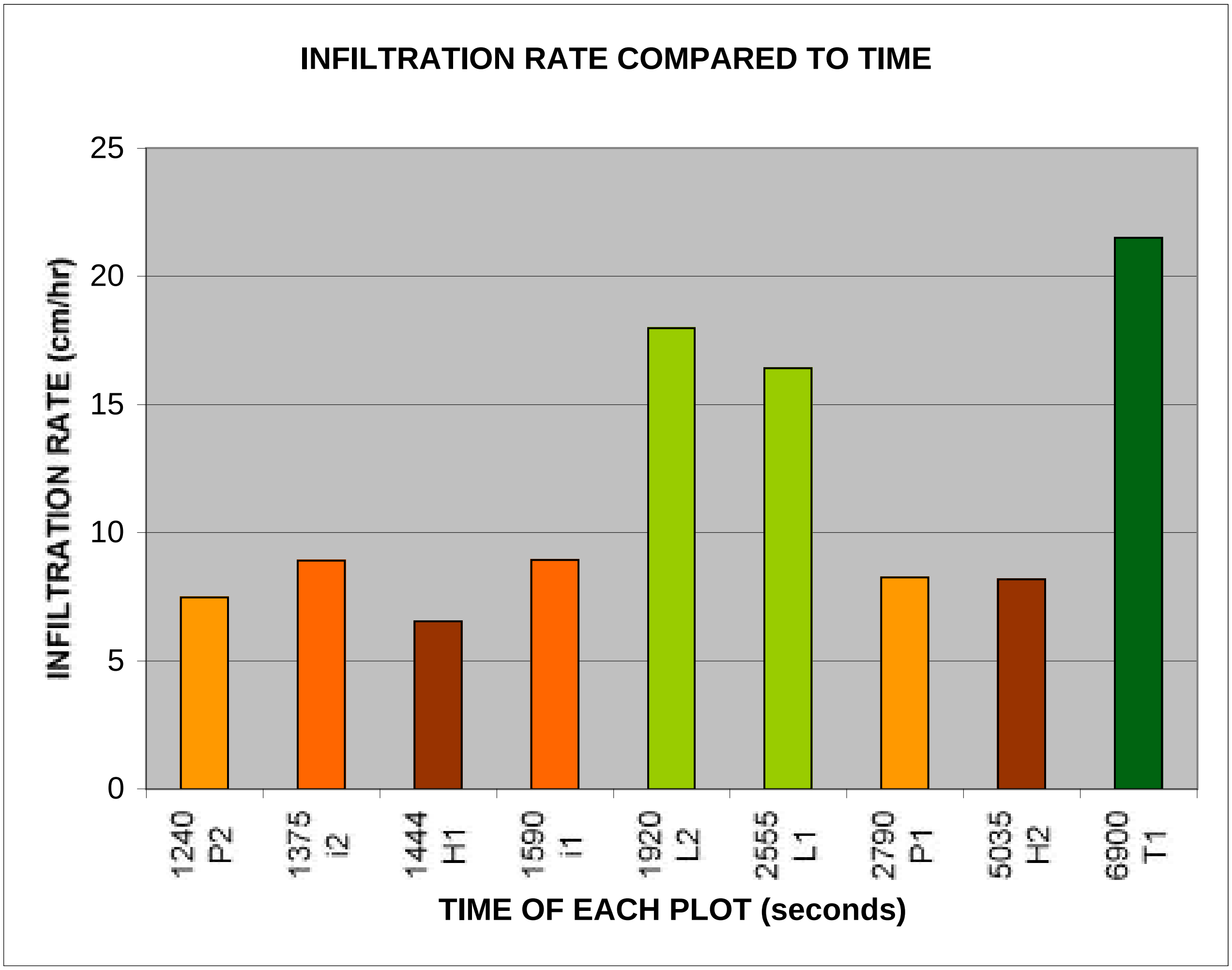
TABLE # 2
COMPARISON CHART

Location	198 East Ave	198 East Ave	86 Brooks	86 Brooks
Surface Firmness,	Heavily Compacted Driveway	Heavily Compacted Driveway	Informal Parking	Informal Parking
Trial	1	2	1	2
Slope	0.052	0.052	0.073	0.073
Total Time (seconds)	1444	5035	1590	1375
Average Rain Rate (cm/hr)	7.25	9.67	8.51	5.6
Runoff Start Time (seconds)	85	120	150	150
Average Sediment Yield (g/bucket)	1	NA	2	NA
Average Infiltration (cm/hr)	6.53	8.17	8.93	8.9
Soil Consistency	Sandy	Sandy	Sandy	Sandy
Area (cm^2)	6125	6125	6125	6125

Comparison Chart

Location	198 East Ave	198 East Ave	198 East Ave	198 East Ave	86 Brooks
Surface Firmness,	Partial Driveway	Partial Driveway	Lawn	Lawn	Thick Grass
Trial	1	2	1	2	1
Slope	0.08	0.08	NA	NA	0.1
Total Time (seconds)	2790	1240	2555	1920	6900
Average Rain Rate (cm/hr)	9.71	9.39	20.5	2.35	26.56
Runoff Start Time (seconds)	245	245	335	210	600
Average Sediment Yield (g/bucket)	1	NA	NA	NA	NA
Average Infiltration (cm/hr)	8.24	7.42	16.41	17.96	21.5
Soil Consistency	Sandy	Sandy	Sandy	Sandy	Sandy
Area (cm^2)	6125	6125	6125	6125	6125

A chart constructed to compare the varying surfaces, and their related factors that cause specific infiltration rates.



H = Heavily Compacted Driveway
I = Informal Parking
P = Partial Driveway
L = Lawn
T = Thick Grass

A Conclusion graph showing the data trends. T1 had the greatest infiltration of the longest period of time. P1 and H2 were rained on for a long time, but had low infiltratation rates. L2 had a greater rate than L1. i1 and i2 are exactly equal bars. P2's infiltration rate is lower than P1's. H1 the compacted drive had the lowest infiltration rate.

Order from lowest infiltration to greatest; compacted drive, partial drive, informal parking, lawn, thick grass.