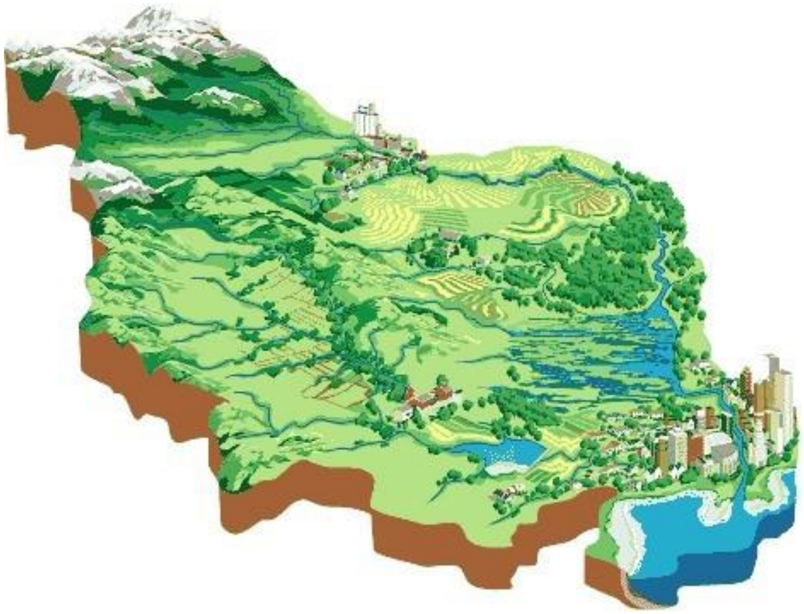
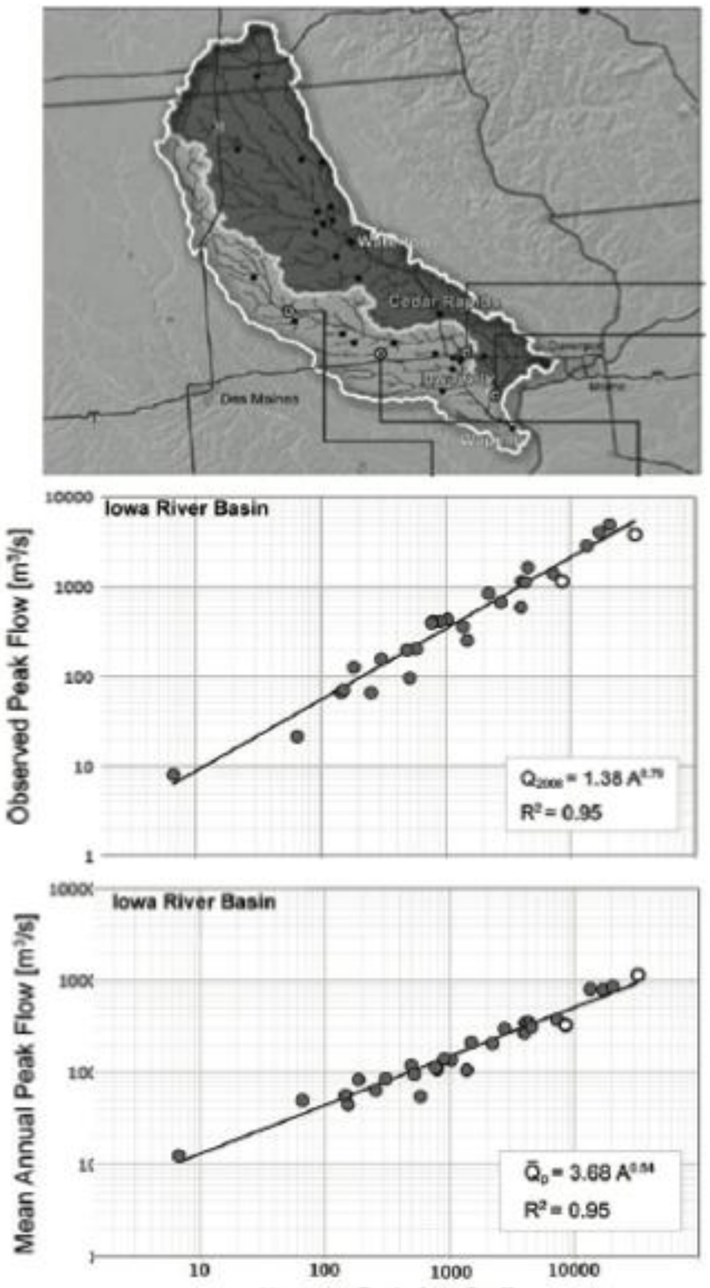
Geospatial Analyses of Urban Drainage Network Structures and Implications for Flood Response in the Kromma Kill Watershed



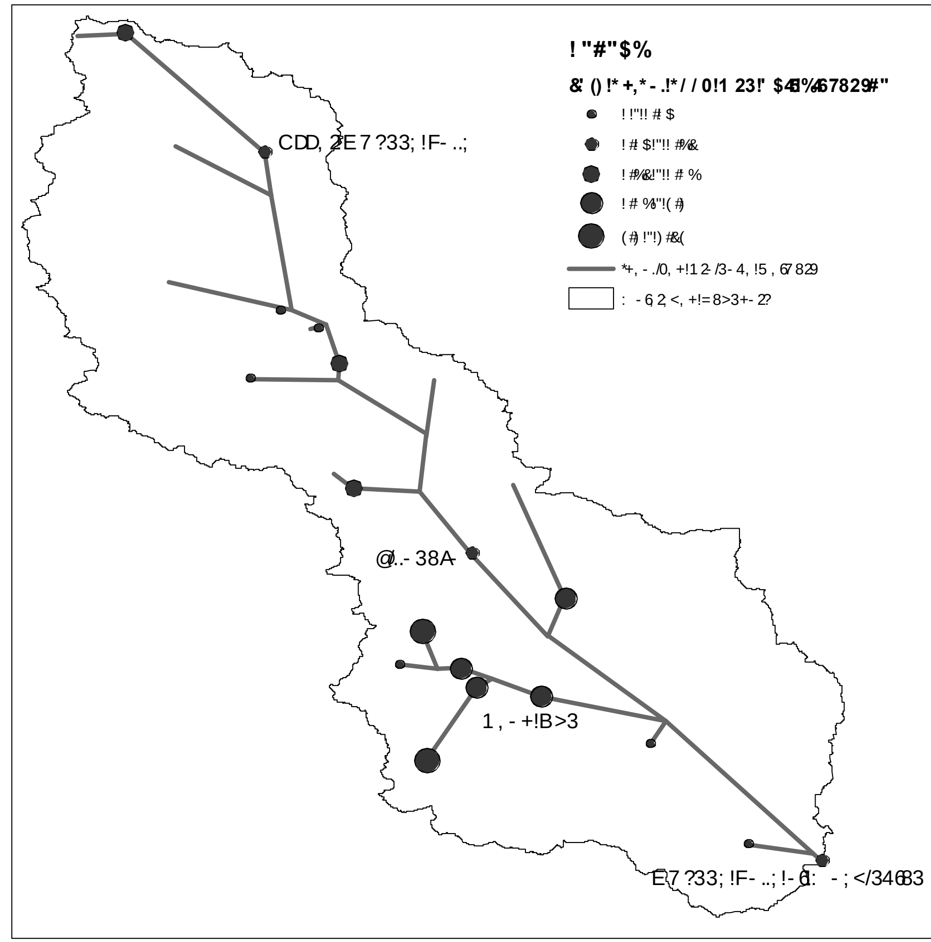
Katherine Meierdiercks & Michele Golden

Department of Environmental Studies, Siena College

LINEAR V. NON-LINEAR RESPONSE ALONG A DRAINAGE NETWORK



Gupta, 2010



Can flood response be predicted from storm event magnitude and drainage area alone?

Heterogeneity of Hydrologic Response in Urban Watersheds

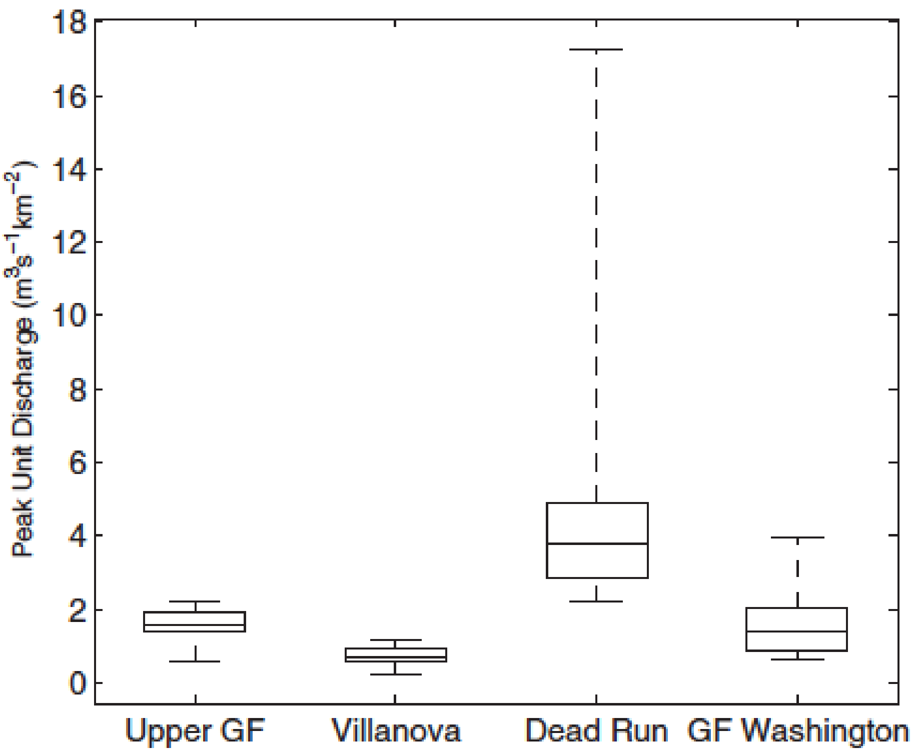
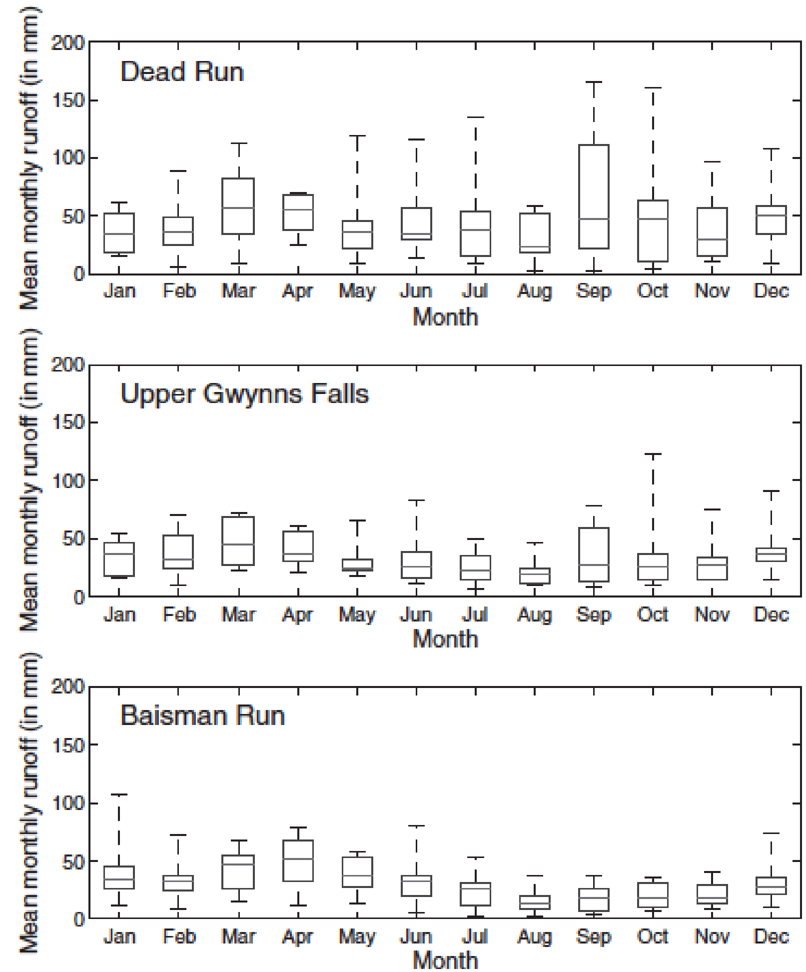
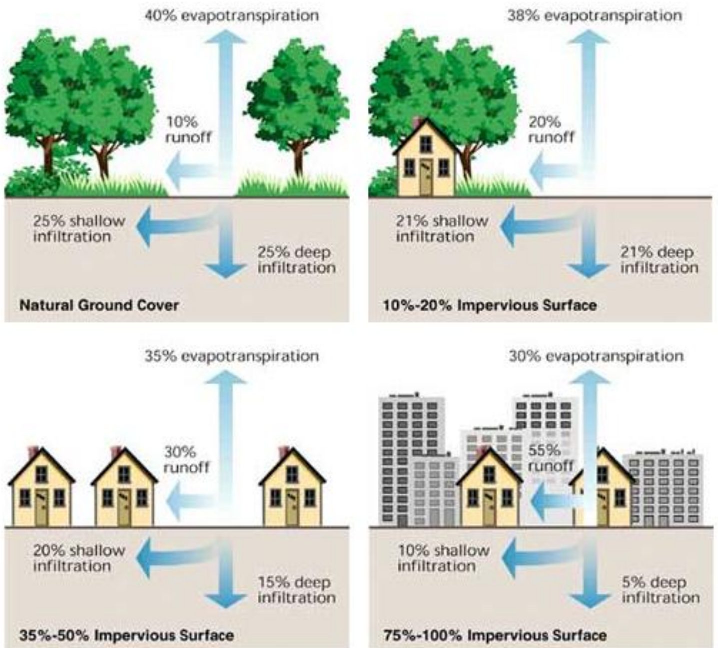


FIGURE 15. Boxplot of Annual Peak Unit Discharge (in $m^3/s/km^2$) for Dead Run, Gwynns Falls at Washington Boulevard, Villanova, and Upper Gwynns Falls (WY 1999-2008).

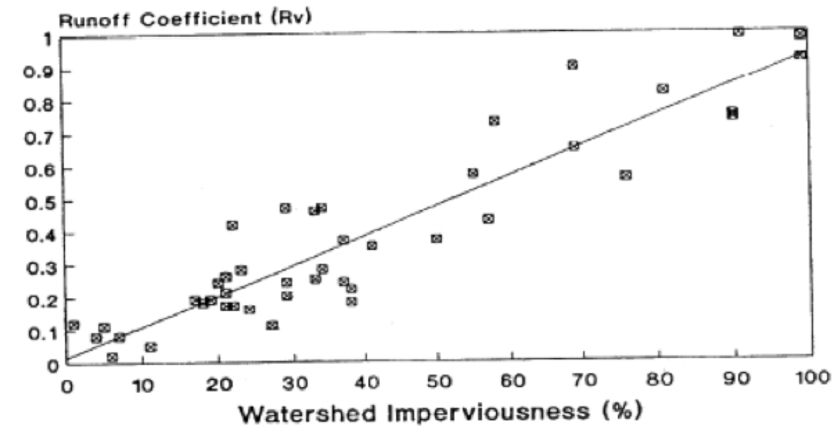


Meierdiercks et al., 2010



From Stream Corridor Restoration: Principles, Processes, and Practices (10/98). By the Federal Interagency Stream Restoration Working Group

Figure 1.2 Relationship between Impervious Cover and the Volumetric Runoff Coefficient (Source: Schueler, 1987)



The runoff coefficient (R_v) expresses the fraction of rainfall that is converted into runoff. The data points reflect over 35 monitoring stations in the U.S.

From 2000 Maryland Stormwater Design Manual

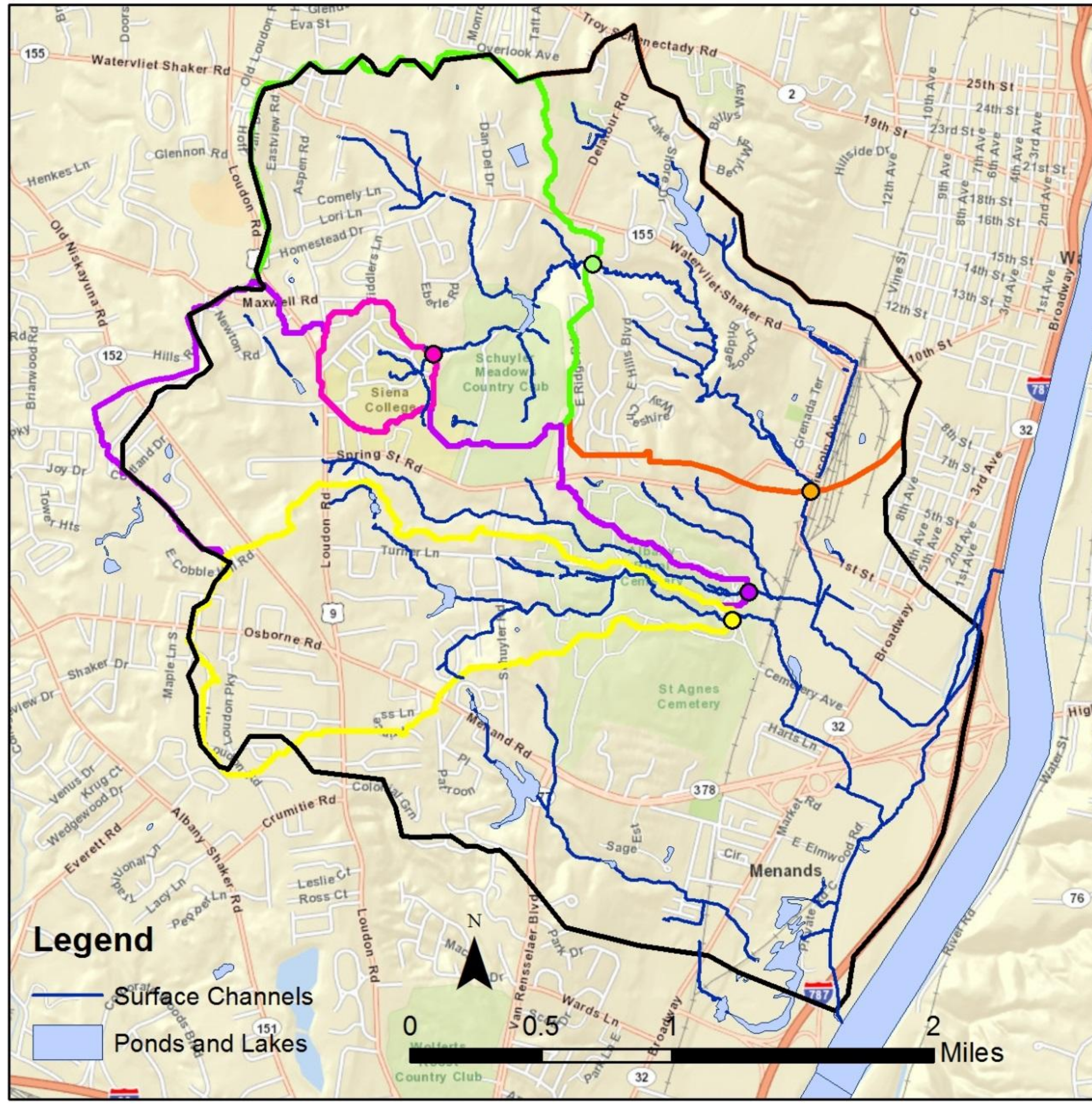
Runoff Coefficient = fraction of rainfall that becomes runoff

Kromma Kill Watershed

QUESTIONS:

(1) Can percent imperviousness explain heterogeneous flood response in the Kromma Kill and its subwatersheds?

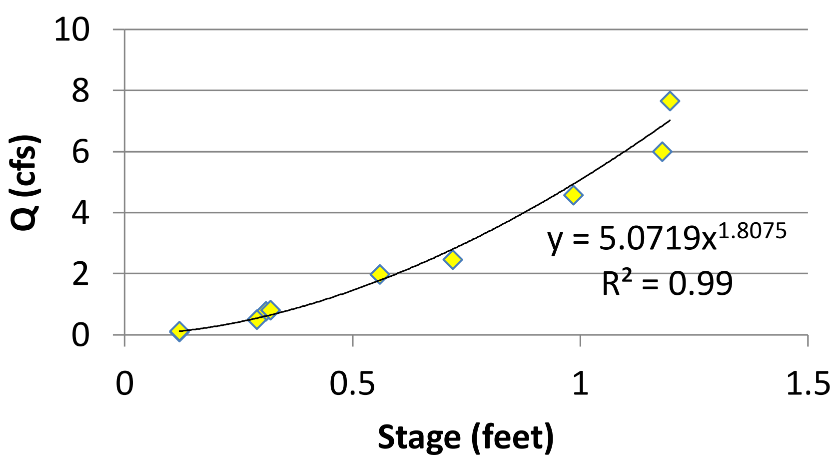
(2) Are there other geospatial characteristics that can be used to better predict flood response in the Kromma Kill and its subwatersheds?



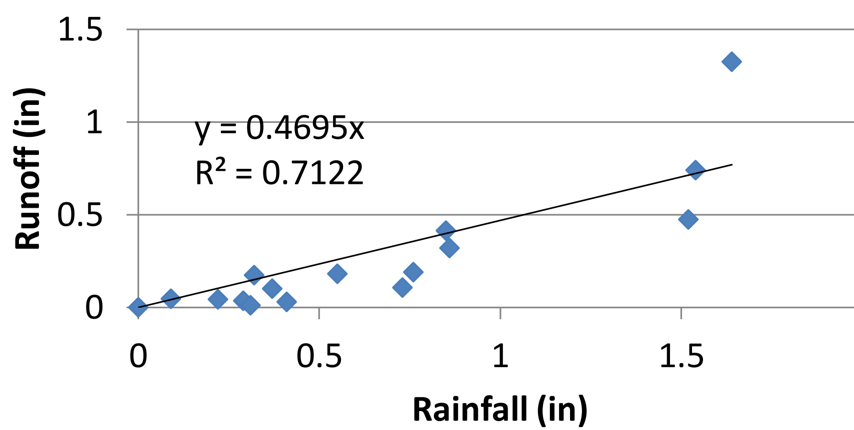
Kromma Kill Watershed:
20 km^2
Town of Colonie, Village of Menands
Tributary to the Hudson River

Quantifying Flood Response

New Hall Rating Curve



East Hills "Average" Runoff Ratio



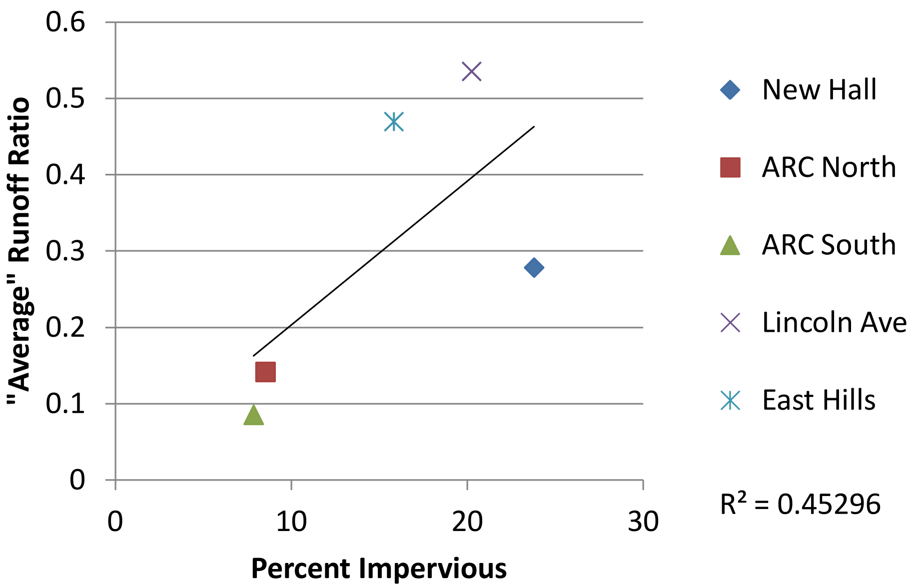
Hydrologic Data

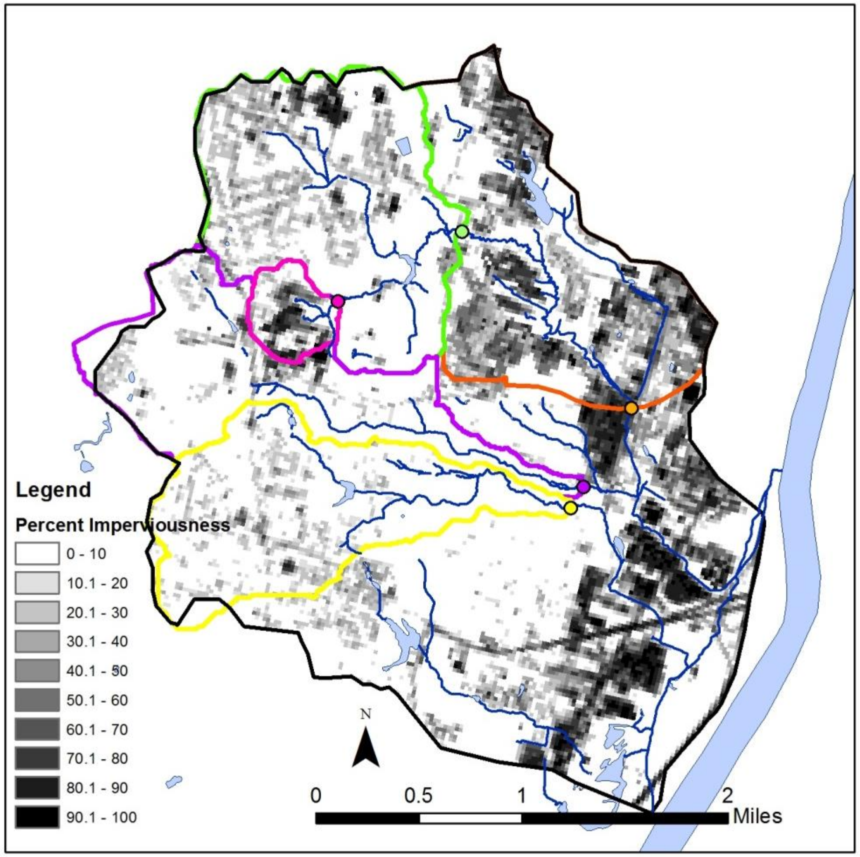
Tuesday, June 25, 2013					
Rainfall (in)	0.42	0.41	0.41	0.41	0.41
Runoff (in)	0.0856	n/a	0.0166	0.0038	0.0293
Peak Unit Discharge (cfs/mi^2)	26.9643	n/a	4.9167	0.8544	3.4969
Runoff Ratio	0.2039	n/a	0.0404	0.0092	0.0714
Thursday, June 27, 2013					
Rainfall (in)	0.78	0.77	0.75	0.77	0.76
Runoff (in)	0.2208	n/a	0.0435	0.0434	0.1898
Peak Unit Discharge (cfs/mi^2)	48.1233	n/a	8.6263	11.2342	33.1959
Runoff Ratio	0.2831	n/a	0.0581	0.0564	0.2497
Friday, June 28, 2013					
Rainfall (in)	0.86	0.83	0.74	0.85	0.85
Runoff (in)	0.2542	n/a	0.0204	0.0956	0.4136
Peak Unit Discharge (cfs/mi^2)	69.5310	n/a	7.2667	23.4983	73.7637
Runoff Ratio	0.2955	n/a	0.0276	0.1125	0.4866
Saturday, June 29, 2013					
Rainfall (in)	0.24	0.23	0.21	0.22	0.22
Runoff (in)	0.0461	n/a	0.0087	0.0040	0.0430
Peak Unit Discharge (cfs/mi^2)	21.3038	n/a	3.3267	1.5650	8.7366
Runoff Ratio	0.1920	n/a	0.0413	0.0180	0.1953
Sunday, June 30, 2013					
Rainfall (in)	0.09	0.08	0.07	0.09	0.09
Runoff (in)	0.0043	n/a	0.0014	0.0008	0.0461
Peak Unit Discharge (cfs/mi^2)	1.9427	n/a	0.1564	0.1365	6.3494
Runoff Ratio	0.0473	n/a	0.0197	0.0084	0.5120
Monday, July 8, 2013					
Rainfall (in)	0.32	0.30	0.23	0.31	0.31
Runoff (in)	0.0436	n/a	?	0.0004	0.0109
Peak Unit Discharge (cfs/mi^2)	18.4694	n/a	?	0.0665	2.2745
Runoff Ratio	0.1364	n/a	?	0.0013	0.0353
Tuesday, July 9, 2013					
Rainfall (in)	1.55	1.55	1.57	1.55	1.54
Runoff (in)	0.4543	n/a	0.1182	0.6477	0.7400
Peak Unit Discharge (cfs/mi^2)	92.4976	n/a	31.1417	221.3032	211.6091
Runoff Ratio	0.2931	n/a	0.0753	0.4177	0.4805
Wednesday, July 10, 2013					
Rainfall (in)	0.83	0.88	1.02	0.86	0.86
Runoff (in)	0.2066	n/a	0.0947	0.2368	0.3197
Peak Unit Discharge (cfs/mi^2)	66.2589	n/a	51.7614	64.0361	85.9184
Runoff Ratio	0.2489	n/a	2.7250	0.2754	0.3718

~35 rain events since 6/1/13

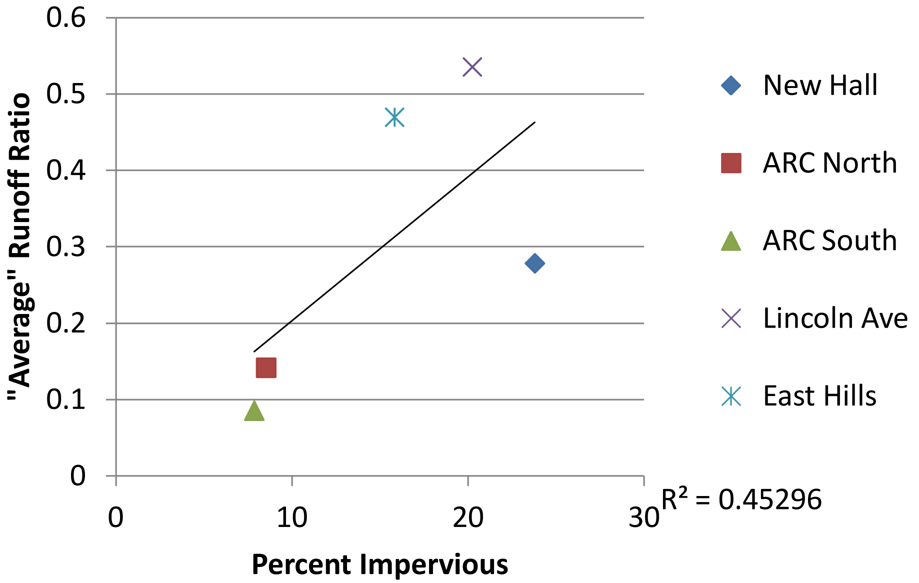
~7.5 inches in June
~4.6 inches in July

Percent imperviousness as a predictor of flood response

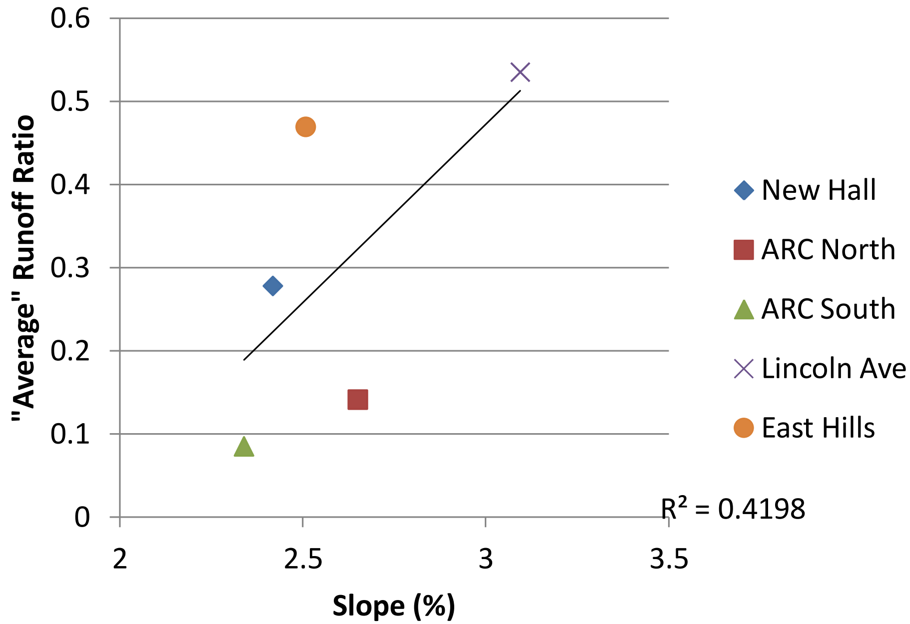




Correlation Coefficient = 0.67



Correlation Coefficient = 0.67



Correlation Coefficient = 0.65

Imperviousness is no better than slope at predicting flood response

Are “pervious surfaces” really pervious?

Compacted urban soils

“Disconnected” Impervious Surfaces

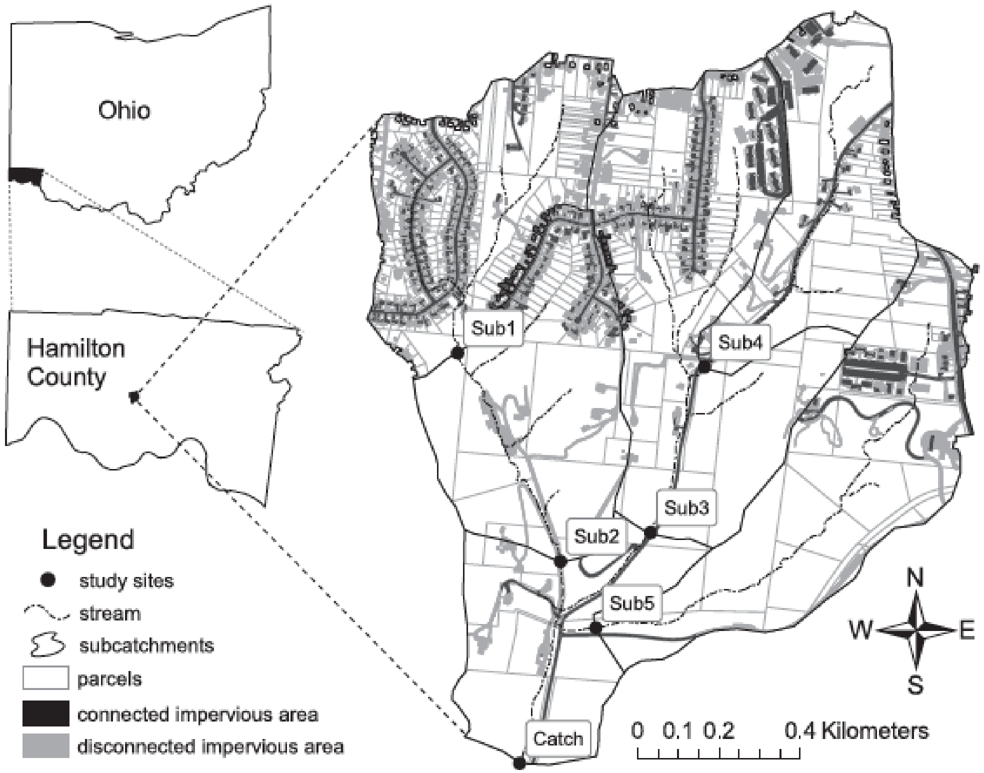


FIGURE 1. Map of Connected and Disconnected Impervious Areas Within the Shepherd Creek Catchment, Hamilton County, Ohio. Catchment (Catch) and subcatchment (Sub1-Sub5) boundaries are based on piped areas.

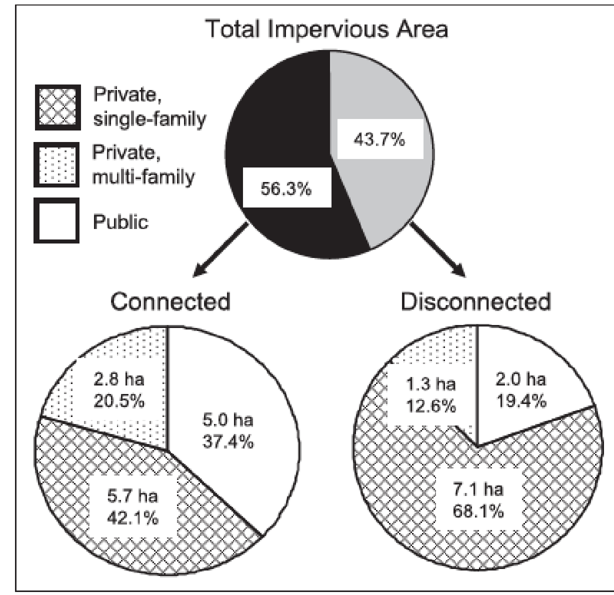


FIGURE 4. Total Impervious Area in the Shepherd Creek Catchment as Connected and Disconnected Based on Property Ownership.

(Roy and Shuster, 2009)

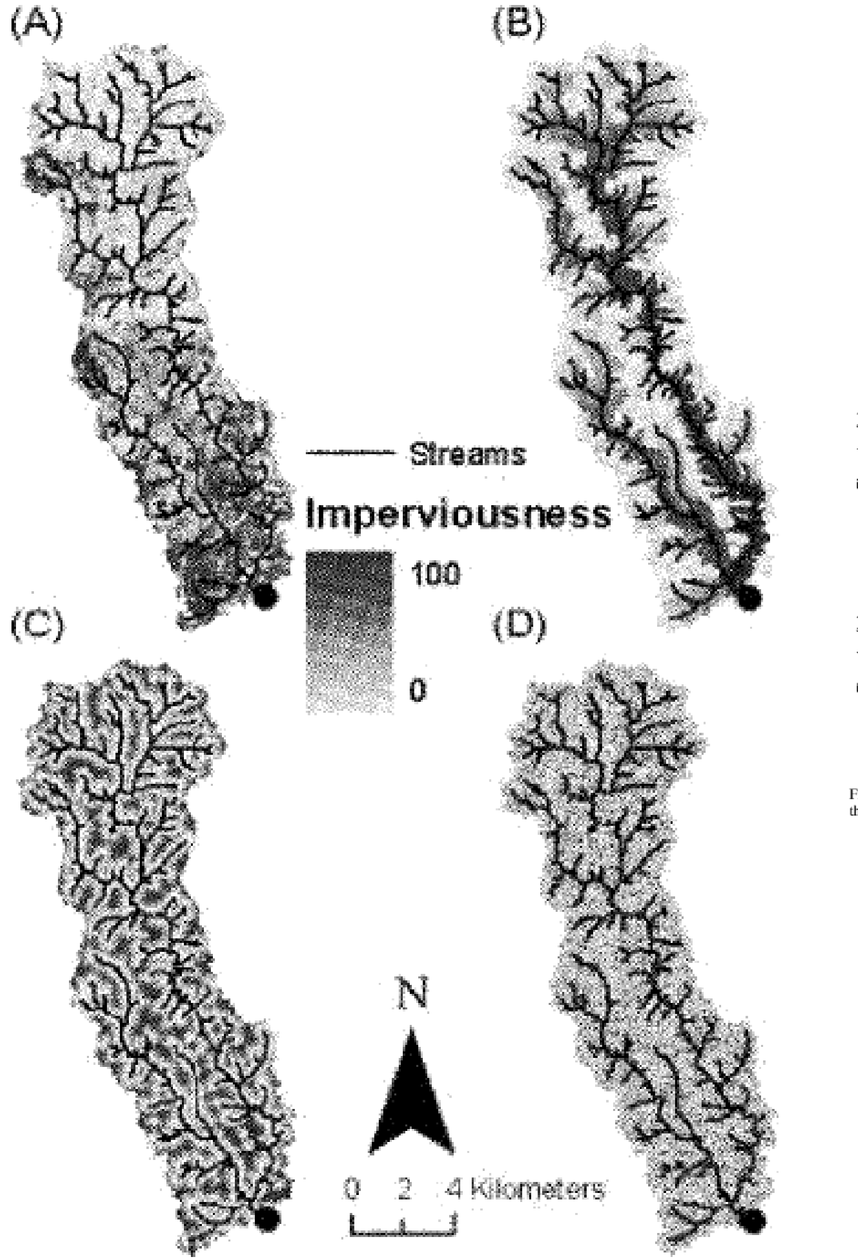


Figure 10. Current and simulated imperviousness patterns used for the comparison of scenarios: (a) current scenario, (b) channel clustering scenario, (c) source clustering scenario, and (d) uniform scenario

Distribution of impervious surfaces

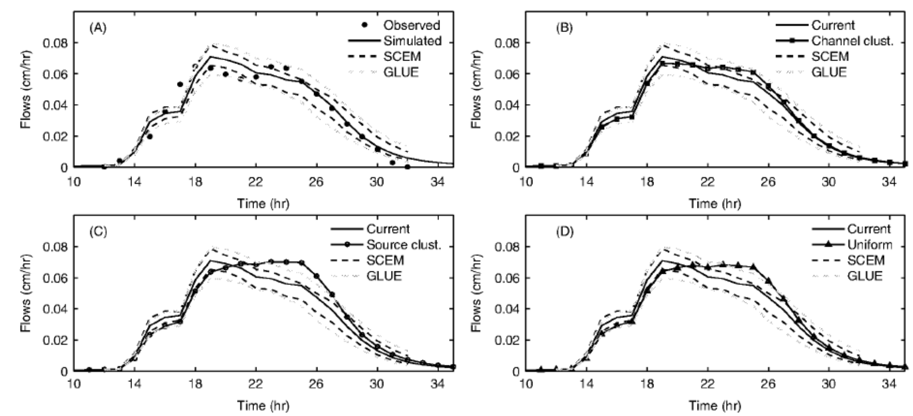


Figure 11. Comparison of the hydrographs obtained from the imperviousness scenarios at HG, including the 95% uncertainty bounds associated with the parameters and the initial condition. (a) Observed flows and current scenario, (b) current and channel clustering scenarios, (c) current and source clustering scenarios, and (d) current and uniform scenarios

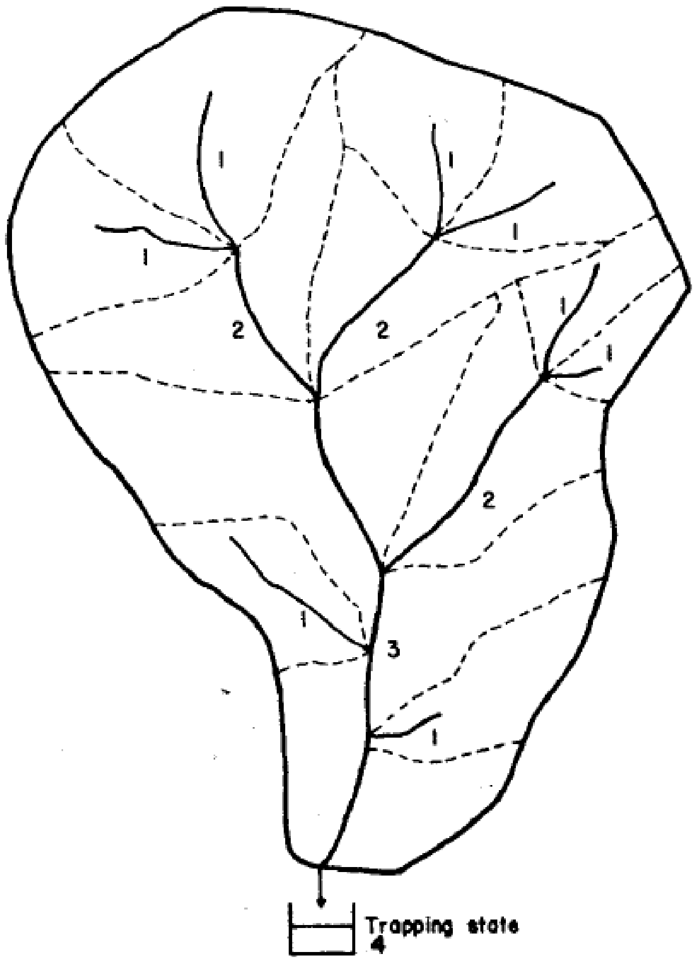
Conclusions: The spatial distribution of impervious surfaces can impact peak magnitude and timing –

•All scenarios led to decreased peak

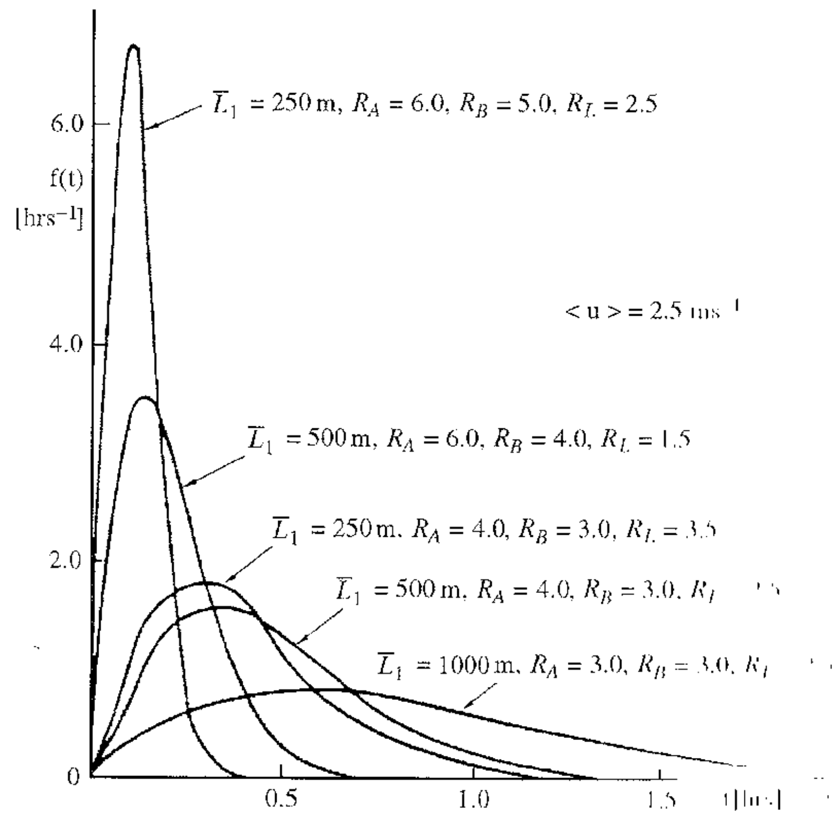
•Source clustering and uniform scenarios led to delayed peak

(Mejía and Moglen, 2010)

Geomorphic Instantaneous Unit Hydrograph (GIUH)



Hypothesizes flood response can be predicted from the geomorphic properties of the drainage basin

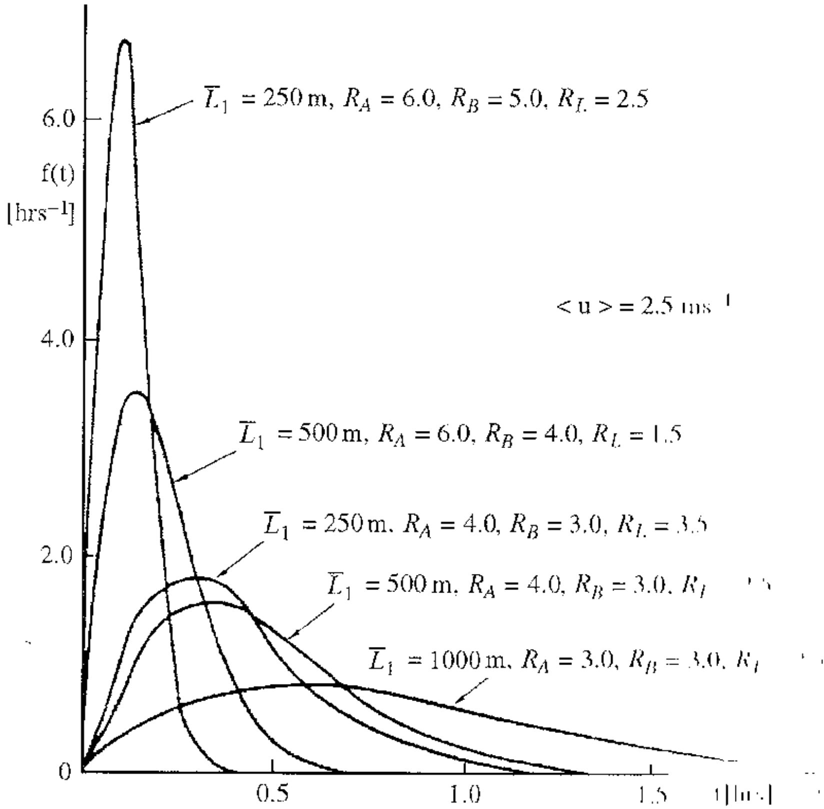


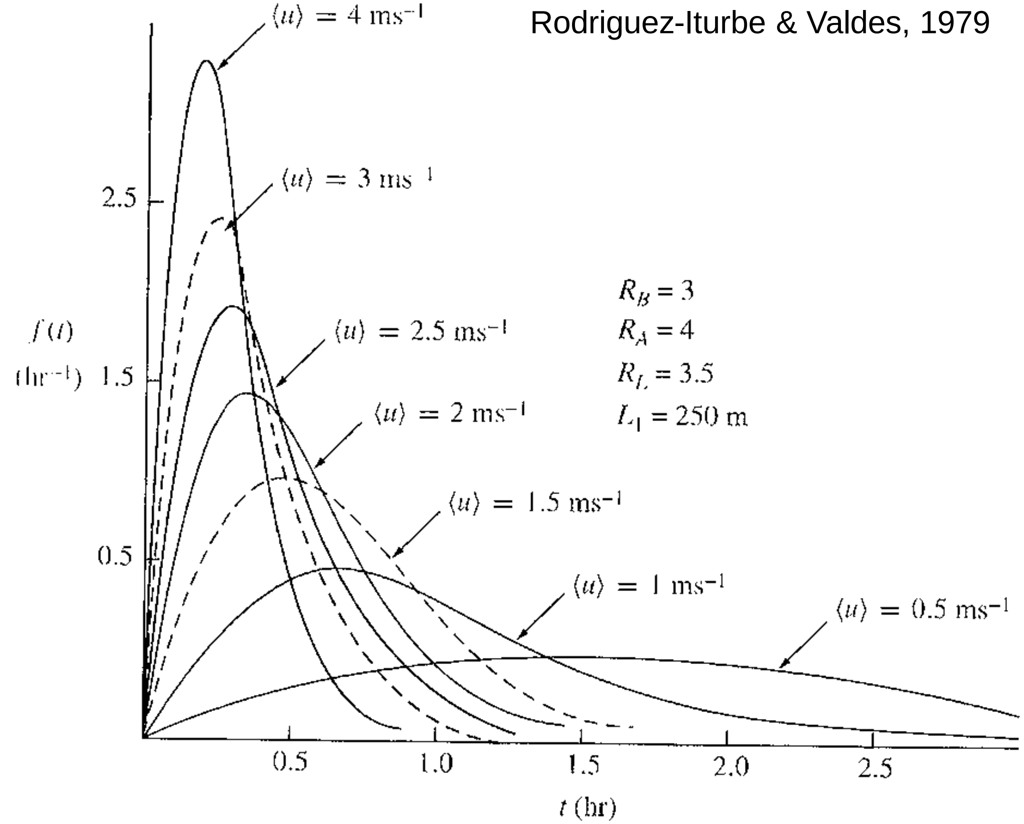
Determine the probability that a rain drop with fall in an area draining into a stream of order ω and follow a path of a certain length

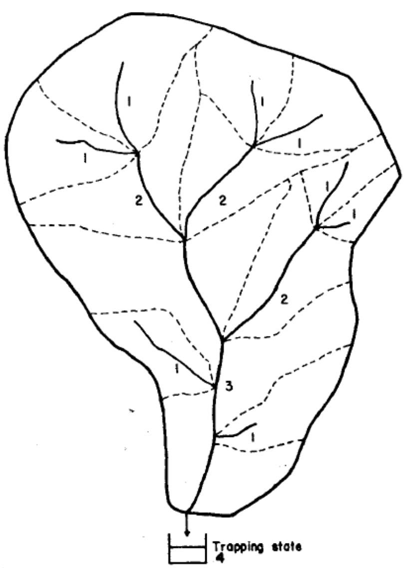
$$Q(t) = i(\tau)\, f(t-\tau)d\tau$$

Q determined by multiplying the rainfall by the GIUH

Rodriguez-Iturbe & Valdes, 1979







GEOMORPHIC PROPERTIES OF THE DRAINAGE BASIN

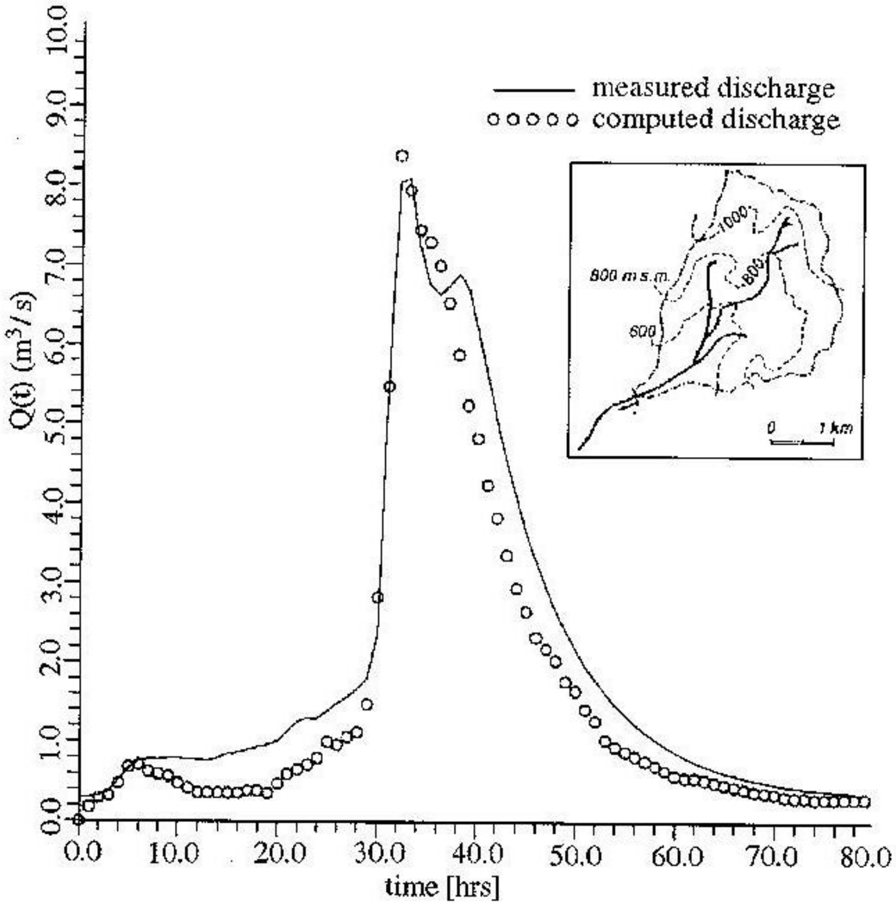
$R_A = A_{i+1}/A_i$ — **Drainage-area ratio** (the larger R_A, the larger the drainage area of higher order streams)

$R_L = L_{i+1}/L_i$ — **Length ratio** (the larger R_L, the longer higher order streams)

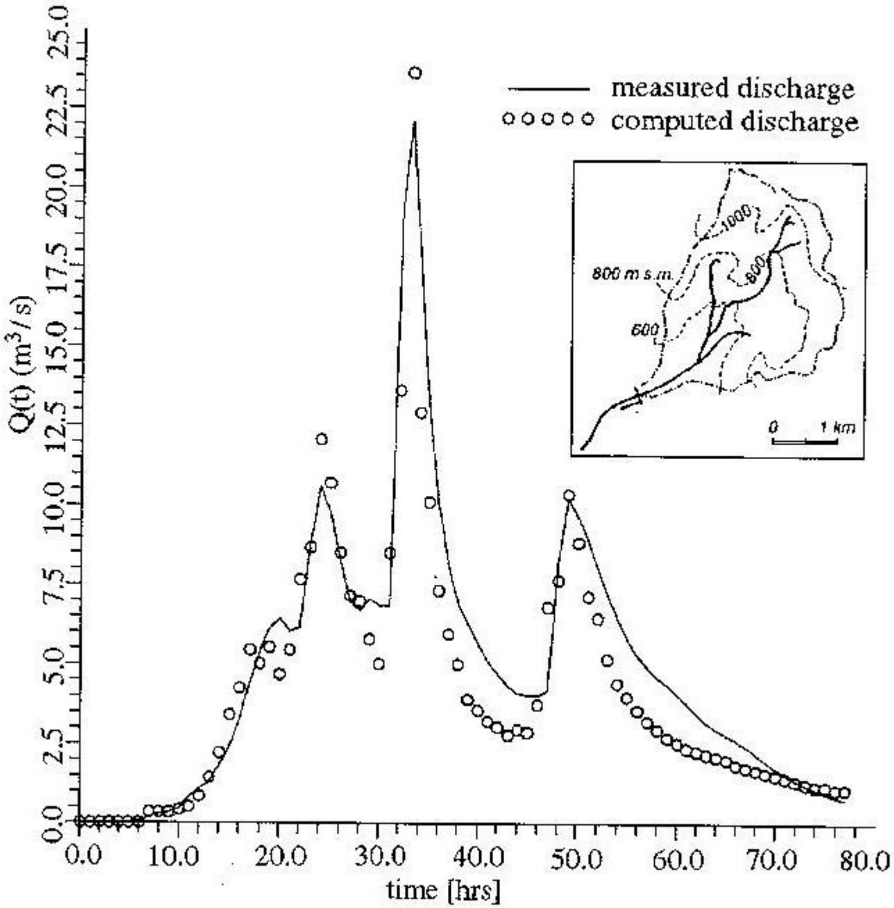
$R_b = N_i/N_{i+1}$ — **Bifurcation ratio** (the larger R_b, the “branchier” the watershed)

L_1 — **Average length of 1st order streams**

U — **Channel velocity**

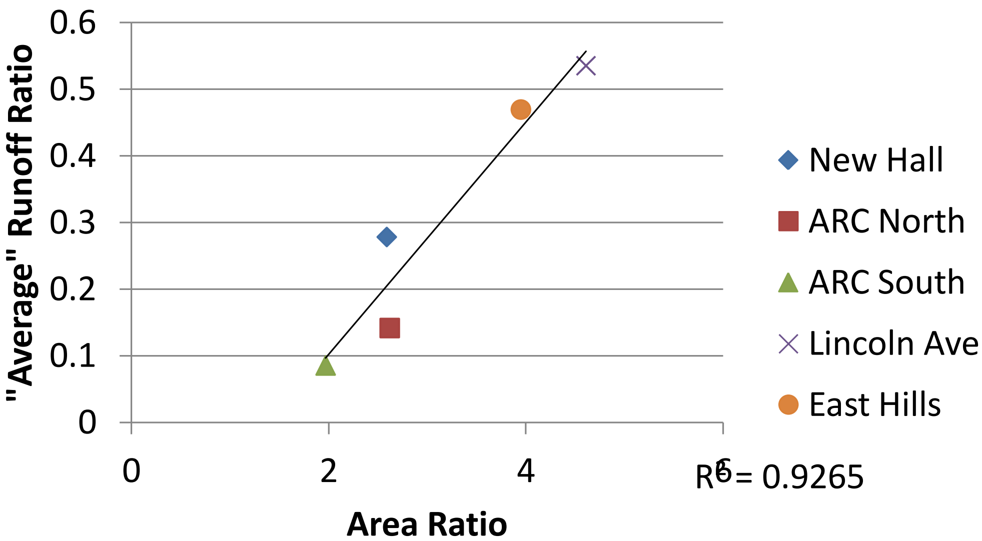


(a)

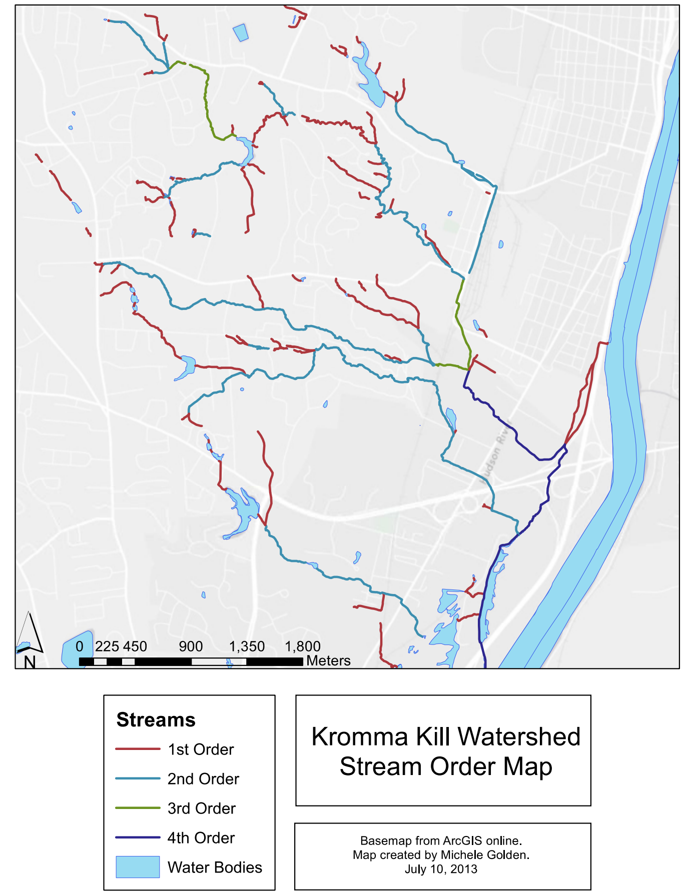


(b)

Rinaldo et al., 1995



Correlation Coefficient = 0.96

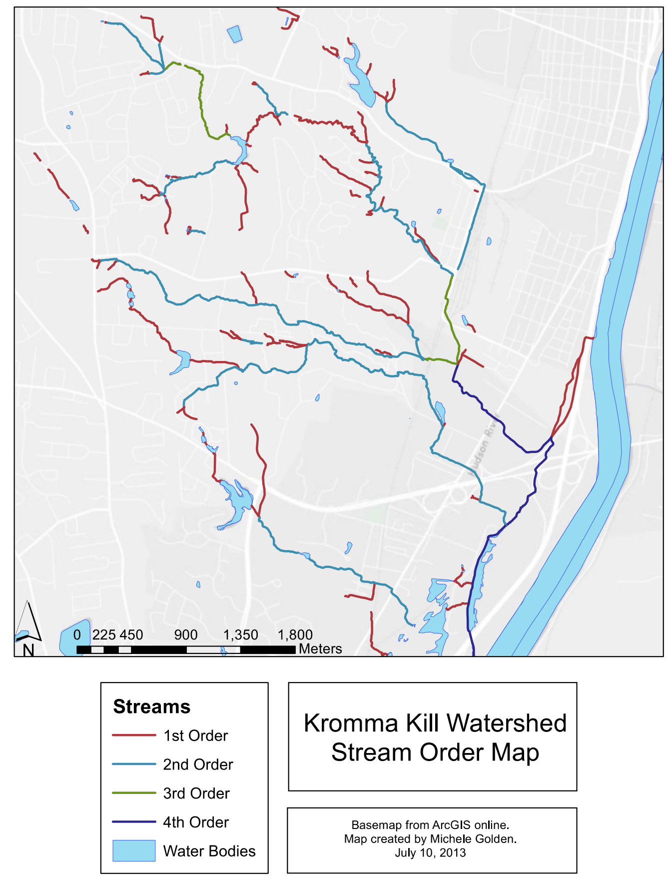


$$R_A = A_{i+1}/A_i$$

<u>Drainage-area ratio</u> (the larger R_A, the larger the drainage area of higher order streams)

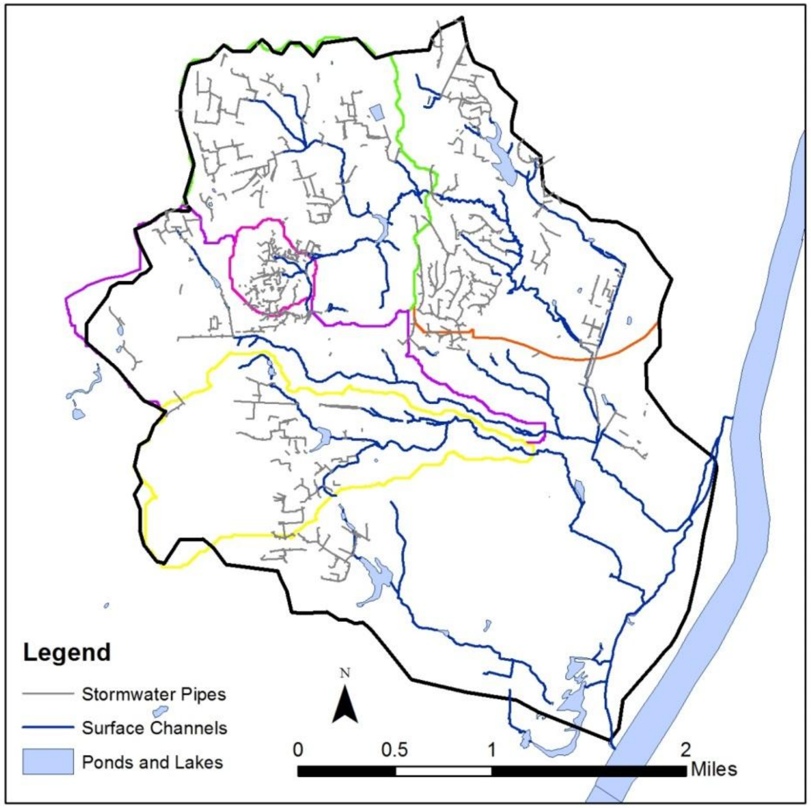
Implications for Stormwater Management??

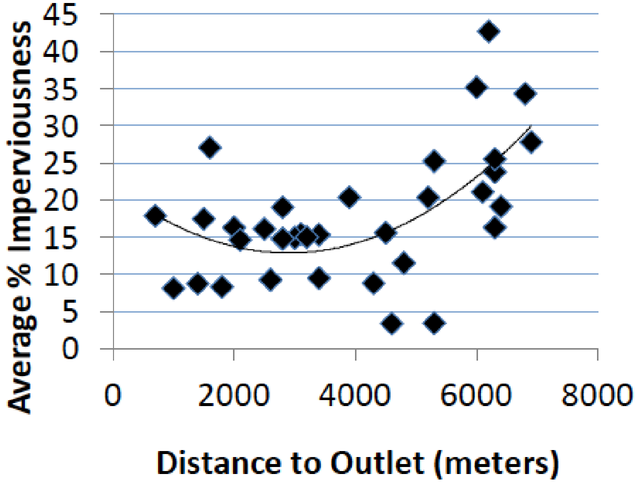
SIENA RAIN GARDEN PROJECT



Future Work

- Include stormwater pipes and roads as extensions of the urban drainage network
- Complete additional GIS analyses
- Two additional subwatersheds
- Integrate water quality data





Concluding Remarks

- The processes that control flooding in small urban watersheds are complex and not well understood.
- Percent impervious surface coverage has traditionally been used as a predictor of flood response. It's good, but not great.
- Geomorphic properties have been used to predict flood response in natural watersheds.
- The geomorphic properties of urban watersheds (as determined using GIS) can help us to better predict flood response and develop more effective watershed management plans.

Thank you

Michele Golden

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NEIWPCC
New England Interstate Water Pollution Control Commission

Hudson River Estuary