Can We Predict Flash Flooding? Models to Estimate Flashiness in the Mid-Atlantic

Rachel Hurley, Prof. David Brandes, Prof. Christa Kelleher
Civil and Environmental Engineering, Lafayette College, Easton PA, 18042

Background

- Due to climate change, heavy rainfall in the Mid-Atlantic Region is becoming more frequent and intense, contributing to the increase in flash flooding.
- The National Weather Service (NWS) currently forecasts flooding based on rainfall and soil moisture which doesn't account for watershed characteristics that could impact the flood responses of streams.
- There is a need for more accurate multivariable flash flood predictor models.

Key Findings

- We determine that flash flood models should be regional specific
- Urban vs regional models experience significantly different flooding behavior
- Wetland cover is a prominent predictor and buffer for flashiness for all regions

Multivariable Models by Region

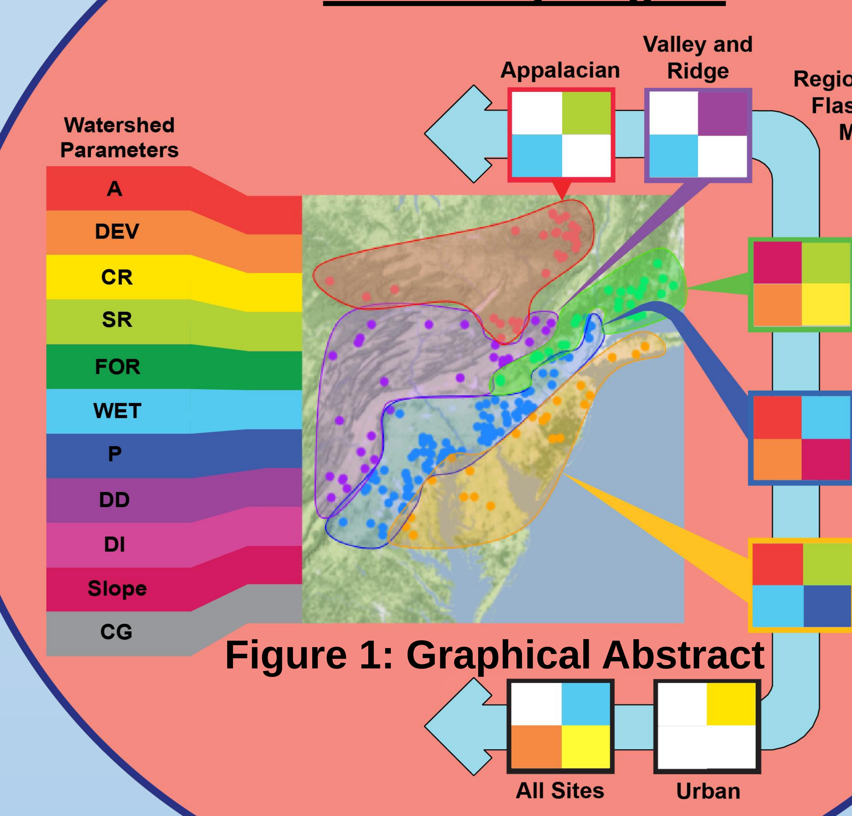

Figure 1: Graphical Abstract

Methods

Materials

Figure 2: Sites and Regions

- We identified 195 sites in the Mid-Atlantic (Fig 2)
- We included eleven watershed parameters in our analysis (Imperviousness was removed due to high correlations with others).
- PoT [1] and RBFI [2] were the flow metrics for analysis (table 1).

Watershed Parameters

Hydraulic Disturbance Index
Area | Compactness Ration
Development | Soil Ratio
Forest Cover | Precipitation
Wetland Cover | Slope
Carbonate Geology
Drainage Density

Scan for parameter descriptions and units

Flow Metrics

Metric	Definition
Richard-Baker Flashiness Index (RBFI)	Oscillations in flow or discharge relative to total flow or discharge, based on daily averages during the water year.
Peaks Over Threshold (PoT)	Flow exceedances of 0.25 m^3/km^2 per water year in 12 h time frame.

Figure 3: Flow Metrics

Statistical Analysis

R Studio 2022.02.1

We used p<0.05(*), p<0.01(**), and p<0.001(***).

BTW: The Mid-Atlantic Region is one of the Flashiest in the US [3]

Modeling

- Data Grouping: There were 7 total model groupings: five by region, one for urban sites, and one full model.
- Parameter Removal: For each model, a parameter with a Pearson's correlation R>0.70 to other parameters, was removed.
- Generation: We used the regsubsets function in the LEAPS package version 3.1 for 4 variable linear models.
- We investigated logarithmic models as well, determining that linear models for RBFI provided better fits according to the adjusted R squared values.

Results

Urban vs Rural

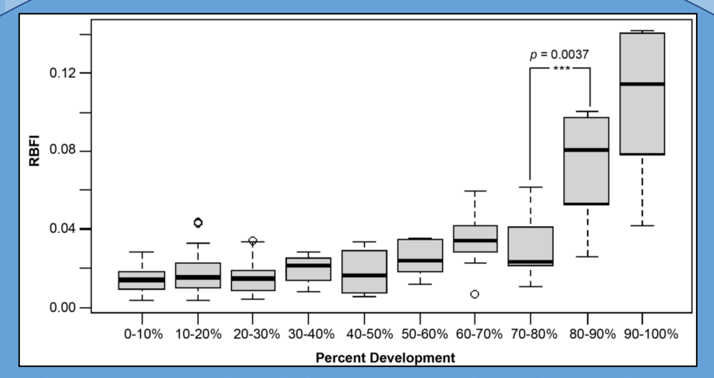

Figure 3: Flashiness Behaviors by Development

- When grouped by 10% development, there was a significant shift (p=0.0037) in RBFI behavior at 80% development. Thus, our urban model contained sites with percent development greater than 80% (Fig 3).
- For all sites, urban, valley ridge and Appalachian models, 1-3 variable models were as sufficient as 4 variable (Fig 4)

Final Models

RBFI	Region (N)							
Paramenter	All (195)	Urban (14)	Pied (79)	CP (19)	VR (28)	NEH (26)	APP (29)	Count
Area	-	-	- 0.005 (<0.001***)	- 0.0034 (0.014*)	-		-	2
Dev	0.016 (<0.001***)	-	0.0054 (<0.001***)			- 0.0084 (0.0041*)		3
FOR		x			x			0
DD					0.0025 (0.023*)			1
Wet	- 0.0038 (0.0013**)	-	- 0.0058 (<0.001***)	- 0.0036 (<0.001***)	-0.0037 (<0.001***)		- 0.004 (0.0020*)	5
DI							-	0
CR	0.0044 (<0.001***)	0.042 (0.0015**)						2
Slope		x	- 0.013 (<0.001***)	x		- 0.012 (0.012*)	x	2
CG					-	- 0.0069 (0.017*)		1
SR				- 0.0053 (0.091)		0.0076 (0.024*)	- 0.015 (<0.001***)	3
P		x		0.0087 (0.010**)				0
Adjusted R^2	0.54	0.55	0.58	0.69	0.36	0.45	0.48	

Legend - Coefficient Absolute Value: 0 – 0.5

Figure 4: Four variable linear models.

Parameter Variations

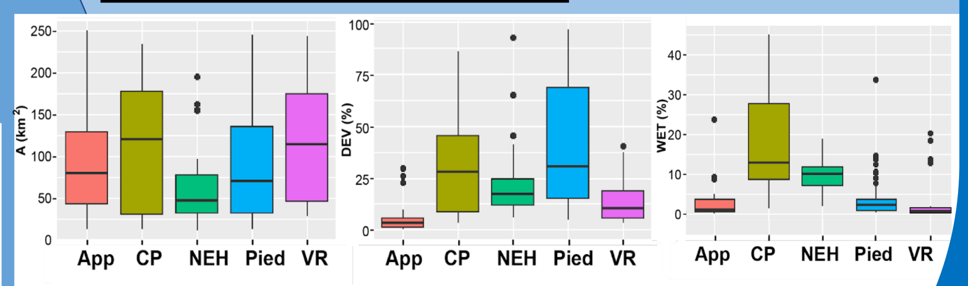

Figure 5: Parameter values by region

- The values and significance of the different parameters vary among regions (Fig 4-5)

For more info email hurleyr@lafayette.edu

Discussion

Flashiness is complex and difficult to predict, especially considering how different watershed regions vary in characteristics and climate. The key finding of our studies include that

- Regional models better predict flashiness due to varied impacts of different watershed parameters
- Wetlands are a universal buffer.
- Rural/suburban watersheds behave similarly, with a shift in flashiness behaviors at ~80% development

The results of our study can be used to more accurately predict flash flooding in the Mid-Atlantic region and can be considered with existing flooding warning systems to better warn the public of flooding events.

References

[1] Karl, T., Melillo, J., & Peterson, T. (2009). *Global Climate Change Impacts in the United States*.
[2] Clark, R. A., Gourley, J. J., Flamig, Z. L., Hong, Y., & Clark, E. (2014). CONUS-Wide Evaluation of National Weather Service Flash Flood Guidance Products. *Weather and Forecasting*, *29*(2), 377–392. https://doi.org/10.1175/WAF-D-12-00124.1
[3]Smith, B. K., & Smith, J. A. (2015). The Flashiest Watersheds in the Contiguous United States. *Journal of Hydrometeorology*, *16*(6), 2365–2381. https://doi.org/10.1175/JHM-D-14-0217.1
[4]Baker, D. B., Richards, R. P., Loftus, T. T., & Kramer, J. W. (2004). A NEW FLASHINESS INDEX: CHARACTERISTICS AND APPLICATIONS TO MIDWESTERN RIVERS AND STREAMS. *Journal of the American Water Resources Association*, *40*(2), 503–522. https://doi.org/10.1111/j.1752-1688.2004.tb01046.x