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Flood Recurrence in Delaware and Otsego Counties, New York

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Abstract

In June 2006, training of tropical moisture resulted in several days of heavy rain over the upper Susquehanna River basin. Delaware and Otsego Counties in New York experienced damaging floods and many roads and bridges were destroyed. This paper addresses the question of how often such an event might come along. Namely, what is the flood recurrence interval (*RI*) for the observed discharges at stream gages in the upper Susquehanna River basin for this flood event? Was it unusual? Would we expect to see this size flood again in our life time?

To address these questions, discharge records from available stream gages were analyzed to estimate flood recurrence, using two different models for the expected distribution of flood events—the log Pearson Type III distribution (the standard model for estimating flood recurrence, essentially a log-normal distribution), and a power law distribution for flood events ($Q(RI) = Q_0\, RI^{a}$, where Q is discharge of a given recurrence, Q_0 is a unit discharge when RI = 1 year, and a is a scaling exponent). The Log Pearson Type III (LP3) model consistently estimates a longer recurrence interval for the 2006 flood event than the power law estimation—with recurrence intervals ranging from 23 to 208 years, roughly 2 to 3 times longer than the power law model. This result has been noted for other basins (Malamud and Turcotte, 2006).

Interestingly, flood recurrence interval varied across the upper Susquehanna basin for this single event. Smaller basins exhibit shorter recurrence intervals for this event, which means that, for each gaging station, the parameters (Q_0 and a) in the power law model vary. We can take advantage of the relation between basin size and *RI* to develop a model for flood recurrence for ungaged streams based on drainage basin area. Two empirical functions fall out of the analysis using the power law distribution—one which relates scaling exponents a to basin area A [$a(A) = bA^c$], and one which relates unit discharges to basin area [$Q_0(A) = dA^e$]. First, exponents for each power law are plotted against basin area, and a new power law describing the change in exponent with basin size is extracted. A similar relation is developed for the power law coefficients (that is, Q_0). Four parameters from these relations, (b, c, d, e) permit us to compute the scaling exponent a and unit discharge Q_0 for a basin of known area. Once the scaling exponent a and unit discharge Q_0 are known, we can reconstruct the flood recurrence power law for the ungaged basin.

Figure 1 Aerial view of Ouleout Creek after the June 2006 flood. Destruction of the season's crops, and alteration of the floodplain were significant problems in Delaware and Otsego Counties. Many highways were damaged, and bridges were destroyed.

Image courtesy of The Daily Star, Oneonta.

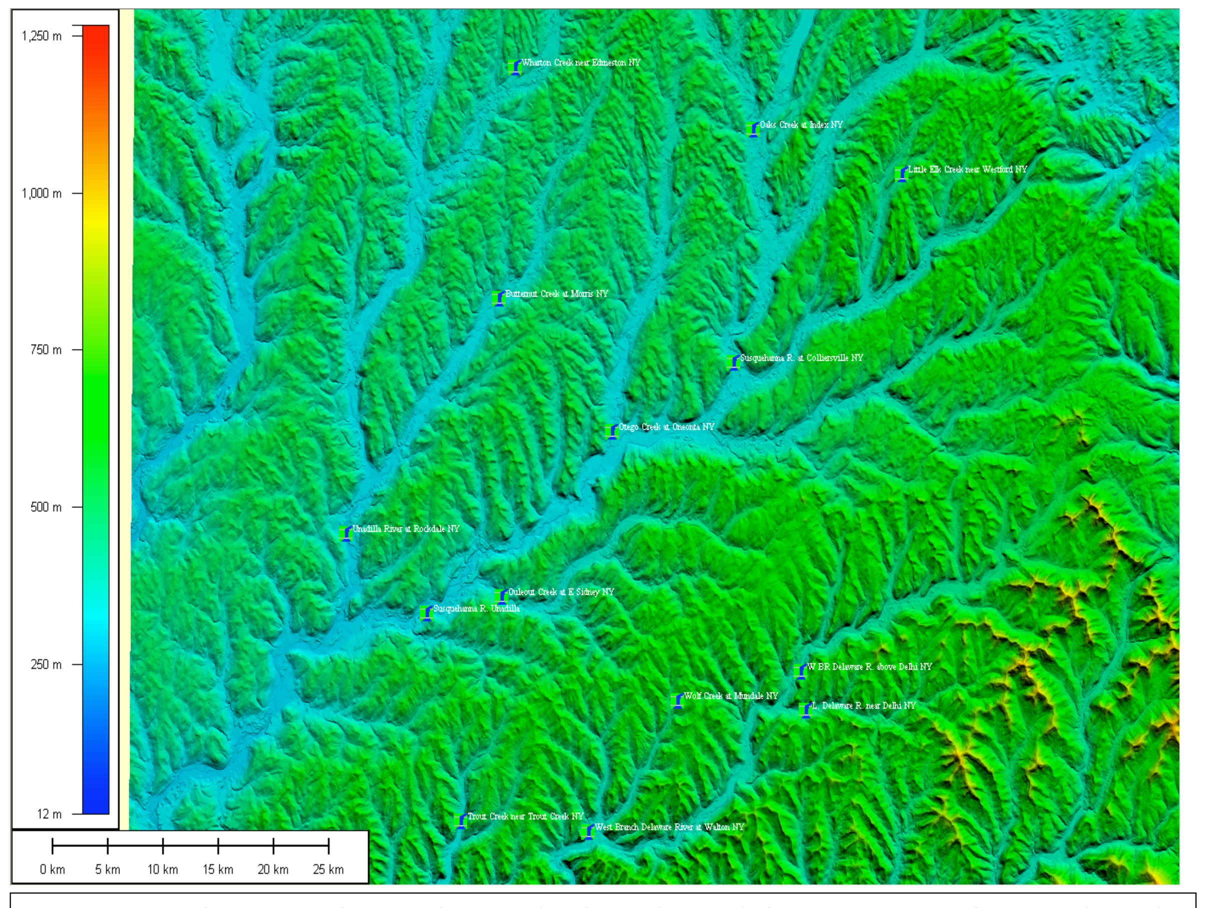

Figure 2. The map above shows the location of the USGS gaging stations in Delaware and Otsego Counties, plotted on top of color shaded relief (elevation data from USGS).

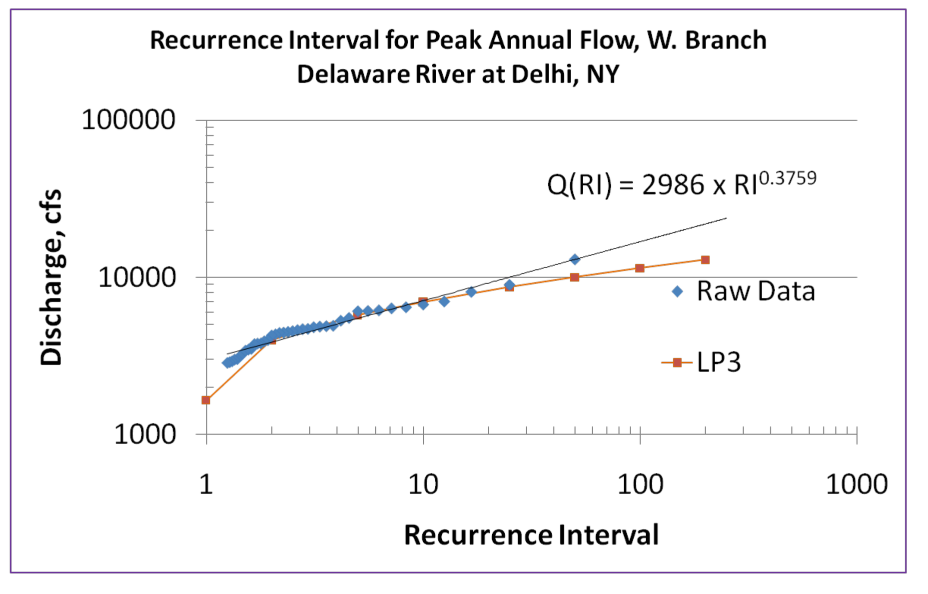

Figure 3. The diagram above exhibits a data set for peak annual flows from a USGS gaging station on the West Branch of the Delaware River. Overlain on top of the data are the two models for recurrence interval examined in this paper, the Log Pearson Type III (LP3), and the power law distribution for flow events. The models diverge at larger recurrence intervals.

River	Peak Discharge (cfs)	Recurrence Interval, LP3	Recurrence Interval, Power Law
Susquehanna River, Unadilla	34,900	121 years	48 years
West Branch Delaware River, Walton	28,600	67 years	32 years
Unadilla River, Rockdale	23,100	167 years	70 years
West Branch Delaware River, Delhi	13000	208 years	51 years
Ouleout Creek	7250	76 years	43 years
Little Delaware River at Delhi	6100	141 years	50 years
Trout Creek	4350	54 years	25 years
Wolf Creek	350	23 years	12 years

Table 1. Comparison of Log Pearson and Power Law recurrence intervals for the 2006 Flood event in Delaware and Otstego counties. Note that the Log Pearson model predicts longer RI for each flow.

Acknowledgements

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Key Observation

Recurrence Interval depends on drainage basin size. Larger basins exhibit less frequent big flows than small basins.

Key Implication

The relation between drainage basin area and recurrence interval permits an empirical development of a power law model for ungaged basins. First, plot power law parameters against area. Extract a model for each. For ungaged basins of known size, we can reconstruct a recurrence interval model for that location.

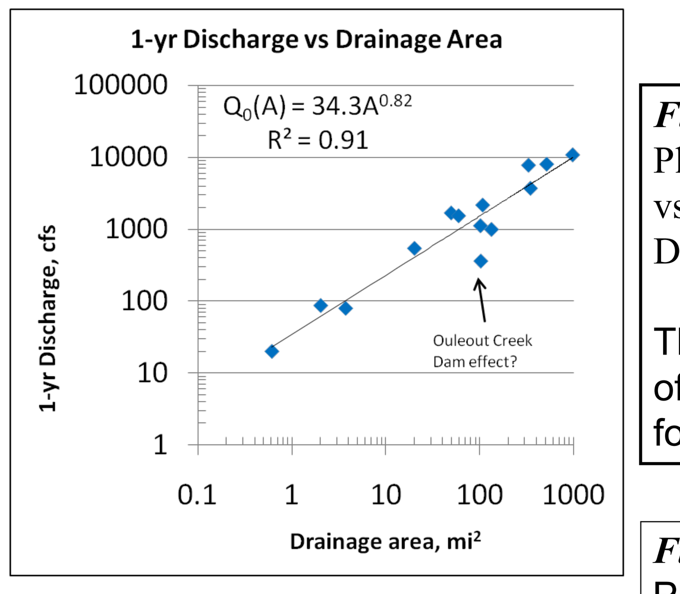

Figure 4.
Plot of the power law coefficients vs drainage basin area for Delaware and Otsego Counties.

The coefficient can be thought of as the 1-yr peak discharge for the given drainage basin.

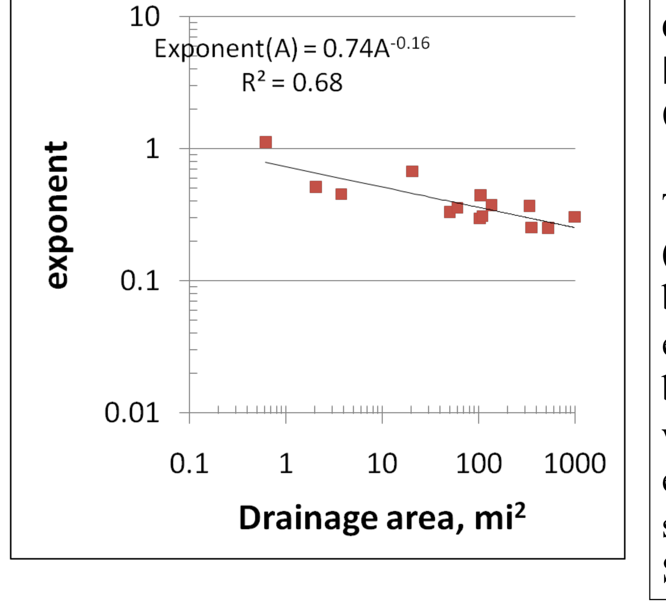

Figure 5.
Plot of power law exponents vs drainage basin area for Delaware and Otsego Counties.

The small value of the exponent (-0.16) indicates a weak relation between drainage area and exponent; in general, smaller basins exhibit a larger exponent, which means that small basins exhibit larger increase in flood size with RI than large basins do. See Figure 3.

Drainage Basin	Area (mi^2)	1-yr Discharge (cfs)	Scaling exponent
Wolf Creek	0.61	20	1.13
Wharton Creek, Edmeston NY	2.02	86.6	0.51
Little Elk Creek, Westford NY	3.73	79.2	0.45
Trout Creek	20.2	539	0.68
Little DE-R, Delhi	49.8	1669	0.33
Butternut Creek, Morris NY	59.7	1528	0.36
Oaks Creek, Index NY	102	1111	0.30
Ouleout Creek, Sidney, NY	103	359	0.45
Otego Creek, Oneonta NY	108	2149	0.31
W. DE-R, Delhi	134	986	0.38
W. Br. Del-R, Walton	332	7678	0.37
Susquehanna River, Colliersville	349	3677	0.25
Unadilla River, Rockdale	520	7956	0.25
Susq-R, Unadilla	982	10719	0.31

Developing a recurrence interval model for a n ungaged catchment

Given an unknown basin's size, we can use the empirical relations in Figure 4 and 5 to obtain the coefficient and exponent for a power law model for recurrence intervals of peak discharge.

Given the two relations for power law parameters

$Q_0(A) = 34.3A^{0.82}$

$Exponent(A) = 0.74A^{-0.16}$

where A is an drainage basin area in mi^2

If an ungaged basin has an area $A = 5$ mi^2, then
$Q_0(A) = 34.3 \times 5^{0.82} = 128$ cfs
$Exponent(A) = 0.74 \times 5^{-0.16} = 0.57$
So $Q(RI) = 128\, RI^{0.57}$

References

Guidelines for Determining Flood Flow Frequency, Bulletin #17B of the Hydrology Subcommittee, Interagency Advisory Committee on Water Data, US Dept. of the Interior, Geological Survey, 1982. http://water.usgs.gov/osw/bulletin17b/bulletin_17B.html

Lumia, Richard, Freehafer, D.A., and Smith, M.J., 2006, *Magnitude and frequency of floods in New York*: U.S. Geological Survey Scientific Investigations Report 2006–5112, 152 p.

Link to Delaware County's imagery and assessment of the 2006 Flood http://www.co.delaware.ny.us/flood2006.htm

Concluding Thoughts

- The Recurrence Intervals for 2006 Flood event ranged from 12 to 208 years
- The range in recurrence intervals appears related to basin size
- An empirical power law model permits estimates of flow recurrence in ungaged catchments in Delaware and Otsego Counties
- This analysis is based on stationarity, that is, the assumption that river flows distributions are not changing through time. This assumption has been severely challenged by hydrologists who point to climate change altering the frequency and size of river flows in various locations around the world.
- Future work documenting channel form, and relating form to discharge, will utilize the ungaged catchment model