Hydrological Characteristics of a Flood Event on the Lower Roanoke River

https://github.com/YFZeng07/ENV790_WDA_FinalProject.git

Yingfan Zeng

1 Rationale and Research Questions

Flooding is one of the most dangerous natural disasters in the world, affecting societies, economies, and ecosystems. With climate change, floods are increasing in intensity and frequency (Bates, Kundzewicz, Wu, & Palutikof, 2008). Flooding is the main stressor for many ecosystems like forests. Globally speaking, there is a strong link between increased flood frequency and forest loss, as well as the intensity and duration of floods (Bradshaw, Sodhi, PEH, & Brook, 2007). Lower Roanoke River Basin has one of the most biodiverse ecosystems in the Southeast United States. It is a typical southeastern alluvial system, contains the largest natural bottomland hardwood forests in the mid-Atlantic region, and is home to a massive number of fish and wildlife species (U.S. Fish & Wildlife Service, 2014). However, forests on Roanoke floodplains have been threatened by flooding there is a strong negative correlation between the vegetation species composition and tree growth rate (Townsend, 2001). Given the lack of study on hydrology characteristics of the Roanoke River flooding, this project selected a specific flood event to investigate the following questions:

1. How long was the flood duration along the river?
2. How was the water height change during a flood event?
3. How did the flood peak move along the river?

2 Dataset Information

2.1 Study Area

The Lower Roanoke River Basin is in southern Virginia and northeastern North Carolina in the United States. Located between the John H. Kerr Dam and the Albemarle Sound, this 600000-ha basin contains over 200 km of the Roanoke River, with floodplains of about 5-10 km in width. There is more than 25000 ha of floodplain forests in the basin (Townsend, 2001), which are deeply affected by the floods of the Roanoke River.

2.2 Study Period

The discharge of upstream dams is closely related to downstream flooding in the Lower Roanoke Watershed. There are 3 dams upstream from the study area and they have a great impact on the basin: the John H. Kerr Dam, the Gaston Dam, and the Roanoke Rapids Dam. There is no major dam below the Roanoke Rapids Dam and its maximum discharge capacity is 20,000 cubic feet per second (cfs). Therefore, in this study, a flood event was defined as a continuous period of the discharge of the Roanoke Rapids Dam above 20,000 cfs. Because it had the largest dam discharge of 35000 cfs, I chose the flooding event between February 27 and March 11, 2019 to examine its hydrological characteristics.

2.3 Water Height Data

Water height data from USGS gages along the Lower Roanoke River were obtained to characterize the flooding hydrology for this flood event. There are 8 USGS gages on Roanoke River from Roanoke Rapids to the Albemarle Sound (Table 1, Figure 1). Their daily water height between 2/1/2019 and 4/5/2019 was retrieved to cover the flooding period.

Table 1: Table 1. The 8 USGS gages on the Lower Roanoke River

Agency	Gage ID	Gage Name	Latitude	Longitude
USGS	02080500	ROANOKE RIVER AT ROANOKE RAPIDS, NC	36.46000	-77.63361
USGS	0208062765	ROANOKE RIVER AT HALIFAX, NC	36.33111	-77.58028
USGS	02081000	ROANOKE RIVER NEAR SCOTLAND NECK, NC	36.20917	-77.38389
USGS	02081022	ROANOKE RIVER NEAR OAK CITY, NC	36.01361	-77.21528
USGS	02081028	ROANOKE RIVER AT HAMILTON, NC	35.94750	-77.20250
USGS	02081054	ROANOKE RIVER AT WILLIAMSTON, NC	35.85972	-77.04028
USGS	02081094	ROANOKE RIVER AT JAMESVILLE, NC	35.81306	-76.89278
USGS	0208114150	ROANOKE RIVER AT NC 45 NR WESTOVER, NC	35.91500	-76.72278

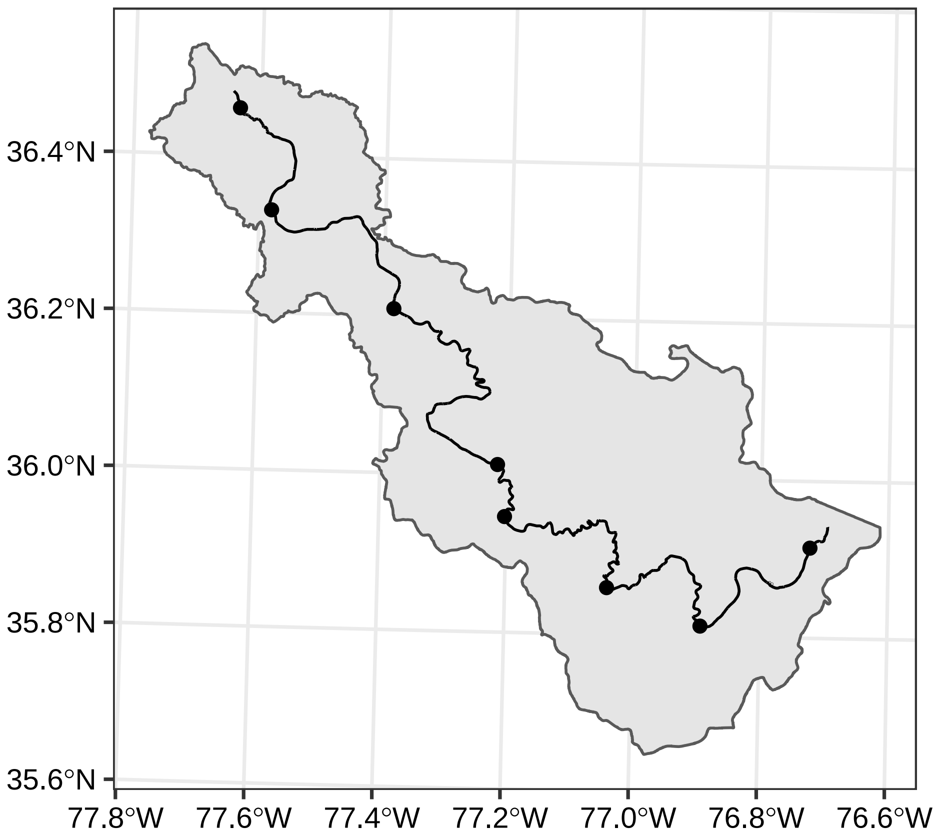

Figure 1: The Lower Roanoke River, its basin and the 8 USGS gages on it.

3 Exploratory Analysis

To gain a general understanding of how water height changed during and after the flood event, I plotted the water height for each gage from upstream to downstream. For most of the gages, the data were too volatile for subsequent analysis. Thus, I calculated the 5-day moving average water height to smooth the trend. The comparison between the original data and the 5-day average as well as the basic changes in water level at each gage is shown in Figure 2.

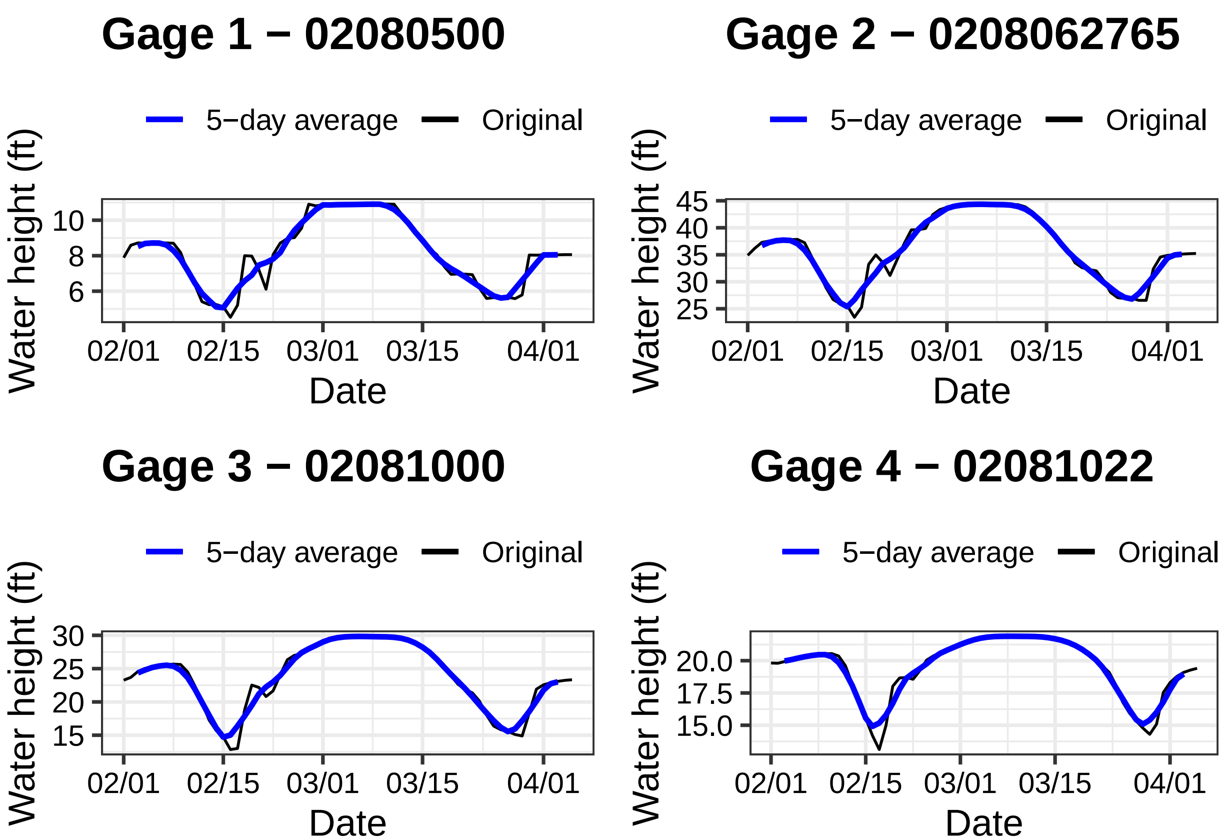

Figure 2: The water height changes during the flood event at Gage 1-4

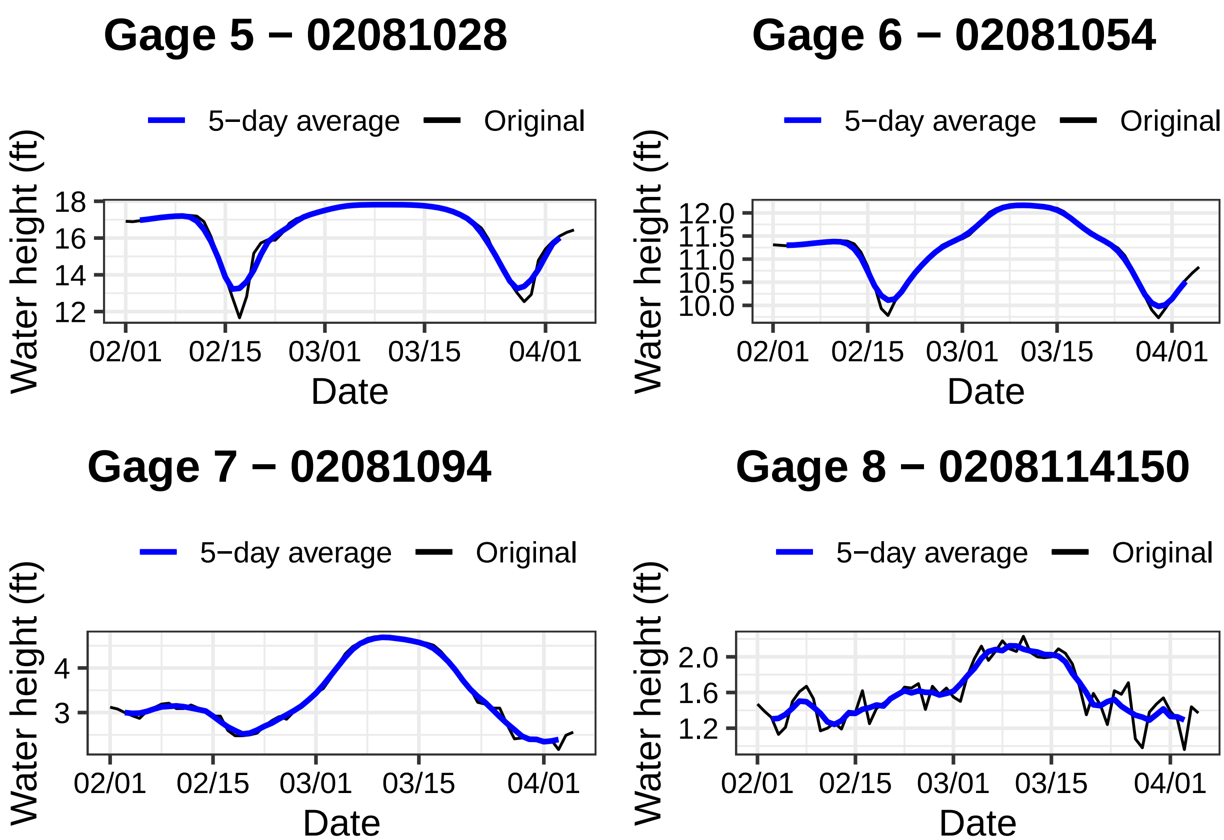

Figure 3: The water height changes during the flood event at Gage 5-8

4 Analysis

The flooding hydrology of this flood event on the Lower Roanoke River was characterized by 3 values: flood duration, water height change rate, and flood peak moving speed. I defined the start date as the first day the water height started to increase, and the end date as the last day the water height decreased after the pulse. The flood duration was determined by the day difference between the start date and the end date. Then, I selected the maximum water level and the lowest water level (normally the first day) during the flooding period and calculated the water height change rate as (maximum level – minimum level)/minimum level. The day with the maximum water height was considered as the flood peak date, and the flood peak day difference at each gage along the river was analyzed. The results were visualized on maps by color gradients.

Table 2: Table 2. The hydrological characteristics at the 8 USGS gages on the Lower Roanoke River (continued below)

Agency	Gage ID	Gage Name	Latitude	Longitude
USGS	02080500	ROANOKE RIVER AT ROANOKE RAPIDS, NC	36.46	-77.63
USGS	0208062765	ROANOKE RIVER AT HALIFAX, NC	36.33	-77.58
USGS	02081000	ROANOKE RIVER NEAR SCOTLAND NECK, NC	36.21	-77.38
USGS	02081022	ROANOKE RIVER NEAR OAK CITY, NC	36.01	-77.22
USGS	02081028	ROANOKE RIVER AT HAMILTON, NC	35.95	-77.2
USGS	02081054	ROANOKE RIVER AT WILLIAMSTON, NC	35.86	-77.04
USGS	02081094	ROANOKE RIVER AT JAMESVILLE, NC	35.81	-76.89
USGS	0208114150	ROANOKE RIVER AT NC 45 NR WESTOVER, NC	35.91	-76.72

Start date	End date	Peak date	Duration	Water level increase rate
2019-02-15	2019-03-26	2019-03-08	39	1.15
2019-02-15	2019-03-27	2019-03-06	40	0.7478
2019-02-16	2019-03-27	2019-03-06	39	0.9864
2019-02-17	2019-03-28	2019-03-08	39	0.4512
2019-02-17	2019-03-28	2019-03-08	39	0.3445
2019-02-19	2019-03-30	2019-03-10	39	0.2191
2019-02-20	2019-04-01	2019-03-10	40	0.9983

Start date	End date	Peak date	Duration	Water level increase rate
2019-03-01	2019-04-05	2019-03-09	35	0.6698

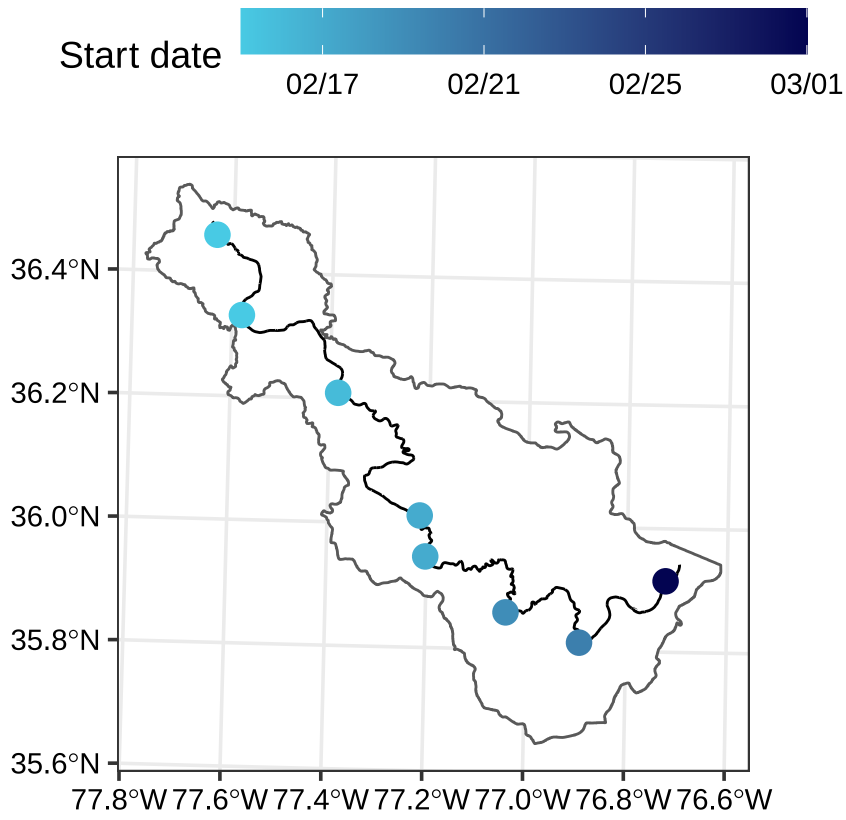

Figure 4: The start date of the flood event at each gages.

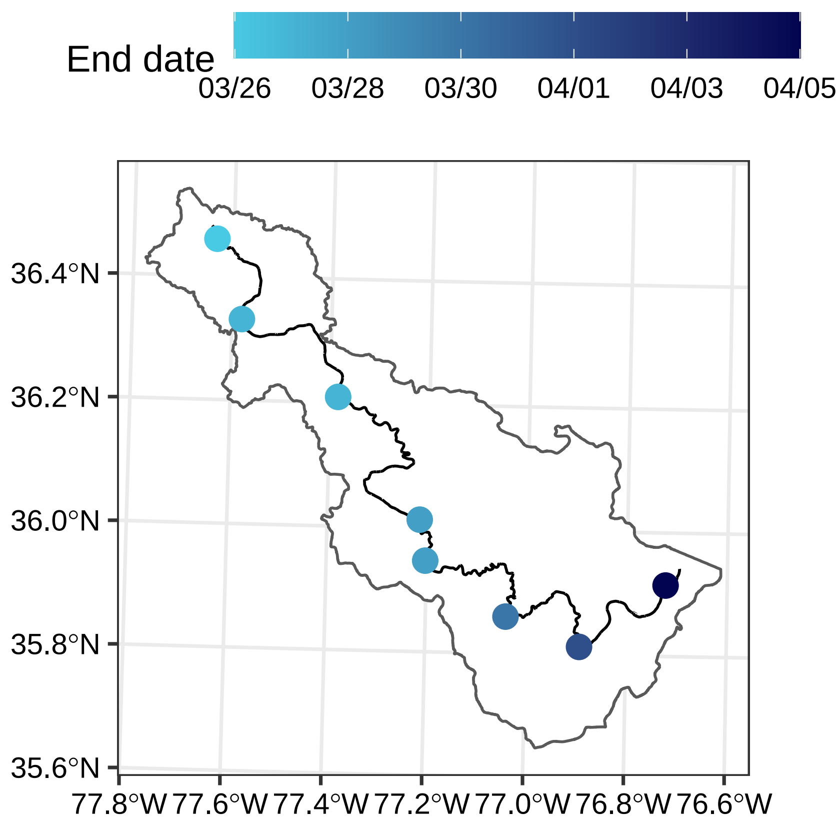

Figure 5: The end date of the flood event at each gages.

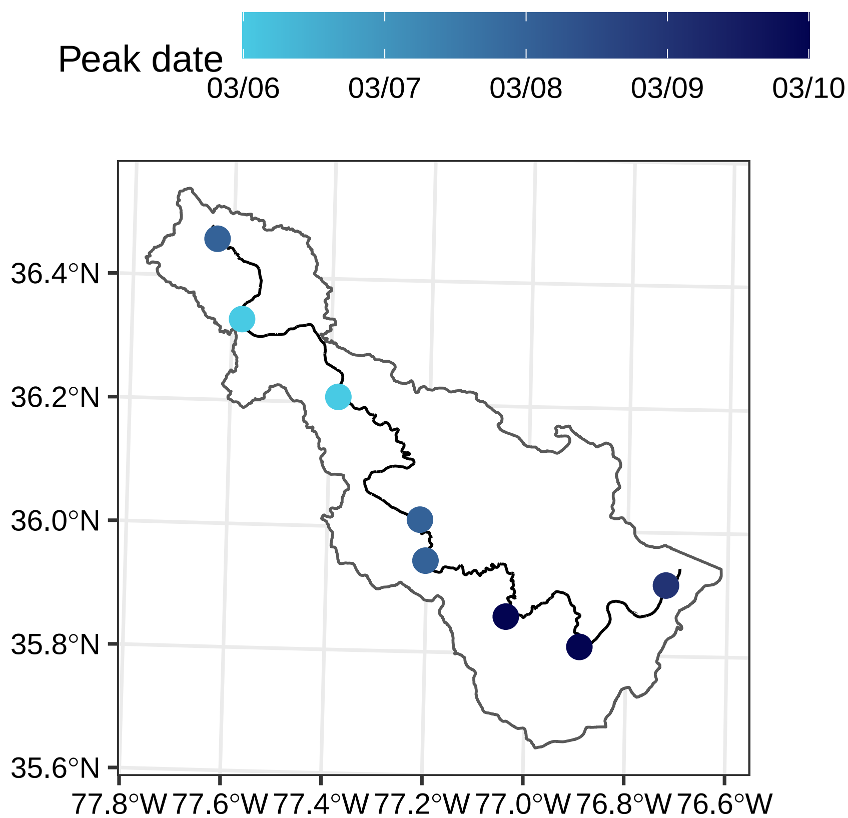

Figure 6: The peak date of the flood event at each gages.

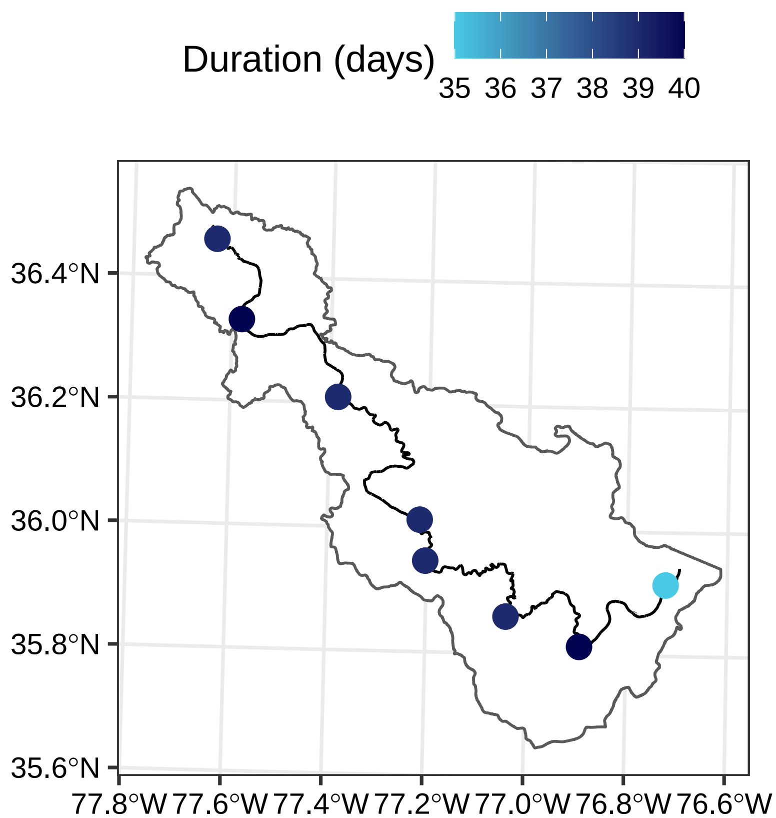

Figure 7: The duration of the flood event at each gages.

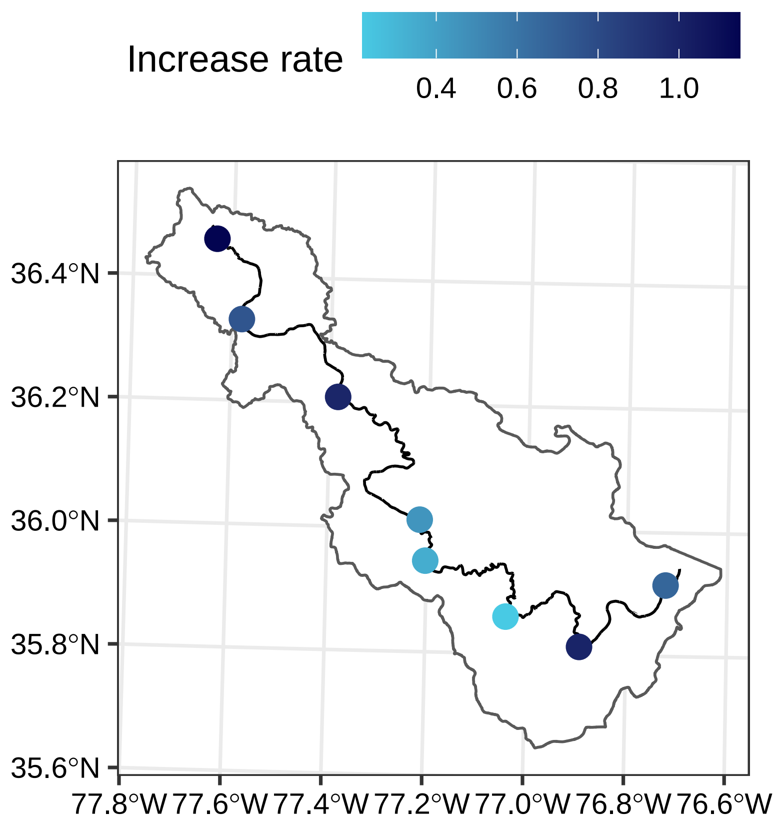

Figure 8: The water level increase rate of the flood event at each gages.

5 Summary and Conclusions

The flood duration ranged between 35 and 40 days at the 8 gages along the river. There was not much spatial trend on flood duration. Except for the most downstream Gage 8, the flood duration of the other gages was 39 or 40 days. This indicated that there was no discernible spatial difference in duration along the river as the flood flowed downstream. By the time it reached the most downstream, much of the water might have been consumed, so the length of the flood at the most downstream gage was significantly shorter.

Although the peak dates were close, the flood start and end dates varied at each gage. The flooding period at the most downstream site (Gage 8) was 15 days later than the most upstream gage at the dam (Gage 1), and the second-to-last downstream point (Gage 7) also had a 5-day lag. It took about 5 days for the water to flow from the upstream to the downstream, meaning that the downstream should expect the flood to arrive 5 days after the dam discharging started.

During a flood event, water level increase rates were high upstream and downstream, but low in the middle of the basin. The most upstream gage at the dam had the highest water level increase of 115%, while the lowest increase rate on the river was only 21% at Gage 6. The water level in the upper and lower reaches had increased by about 70% or more, while in the middle river there was only about 45% or less. This might be due to the narrow channels in the upper and lower reaches, with wide channels and broad floodplains in the middle basin. In fact, a lower water level increase rate might mean more overbank flow and more severe flooding.

In conclusion, for the flood event in March 2019, the duration at different locations along the river was similar, while there was about a 5-day lag of the flooding period from upstream to downstream. The water level increased more in the most upstream and downstream areas, and less in the middle basin. This study deepened the understanding of flooding hydrology on the Lower Roanoke River and could serve as a reference for future flood prevention and control.

6 References

Bates, B. C., Kundzewicz, Z. W., Wu, S., & Palutikof, J. P. (2008). Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat: Geneva, Switzerland. The American Midland Naturalist, 168(1).

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Townsend, P. A. (2001). Relationships between vegetation patterns and hydroperiod on the Roanoke River floodplain, North Carolina. Plant Ecology, 156(1), 43-58.