Appendix

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Data Source

The daily area weighted mean precipitation data used for these analyses came from USGS gauging stations in Boone, Greensboro, and Greenville. The HUC codes for each station are as follows: - Boone HUC 050500010201 - Greensboro HUC 030300020105 - Greenville 030201030403 We used these data to analyze whether precipitation characteristics have changed for the different college campuses located in each of these cities since the last major investment in infrastructure that wrapped up in 1999.

Data Wrangling

We began our analysis by preparing the data to analyze different storm event durations, focusing on 24-hr and 72-hr storm events. To get estimates for 72-hr storm events we took a rolling sum across a 3 day window to get an estimated 72-hour storm event for each day. For 24-hr storm events we took a moving average of 24-hr data over a 7-day window to ensure each event being analyzed was statistically different from the others, which is an assumption of the Weibull recurrence interval calculation.

For the 24-hour data we then found monthly maximum 24 hour events for each month in each year of available data. The maximum 24-hour storm event for each month from 1980-1999 and 2000-2016 was then used to calculate recurrence intervals for 24-hour storm events pre- and post-2000.

For the 72-hour data we found monthly maximum 72 hour events for each month in each year. The maximum 72-hour storm event for each month from 1980-1999 and 2000-2016 was then used to calculate recurrence intervals for 72-hour storm events pre- and post-2000.

Recurrence Interval Calculation

We calculated both the Weibull and Hazen recurrence intervals for Boone, Greensboro, and Greenville's monthly maximum 24-hour and 72-hour storm events from 1980-1999 and from 2000-2016. Recurrence intervals using each method differed due to Weibull being more conservative (assigning higher return periods for more extreme events), and Hazen being less conservative (assigning a smoother distribution of recurrence intervals). Due to the large sample size and wanting to have conservative estimates based on the application of using these return periods being used for flood mitigation, we moved forward with using Weibull return periods for our decision making process.

After calculating return intervals for each 24-hour and 72-hour storm event in each time frame of interest (pre- and post-2000) we plotted the difference in return periods from 1980-1999 and from 2000-2016 for each city.

Since 1980-1999, events of the same likelihood have become more intense. For example, in Boone, a 1 inch 24-hour event from 1980-1999 had a 37.5% chance of occurring. More recent data (2000-2016) shows that the same likelihood event would be associated with around a 1.25 inch 24 hour event. More rain in the same amount of time is more likely now than it was in 2000.

The lines of best fit on each of the above graphs represent the probability distributions of different intensity 24-hr and 72-hr storm events (range on y-axis) in 1980-1999 and 2000-2016. We used these probability

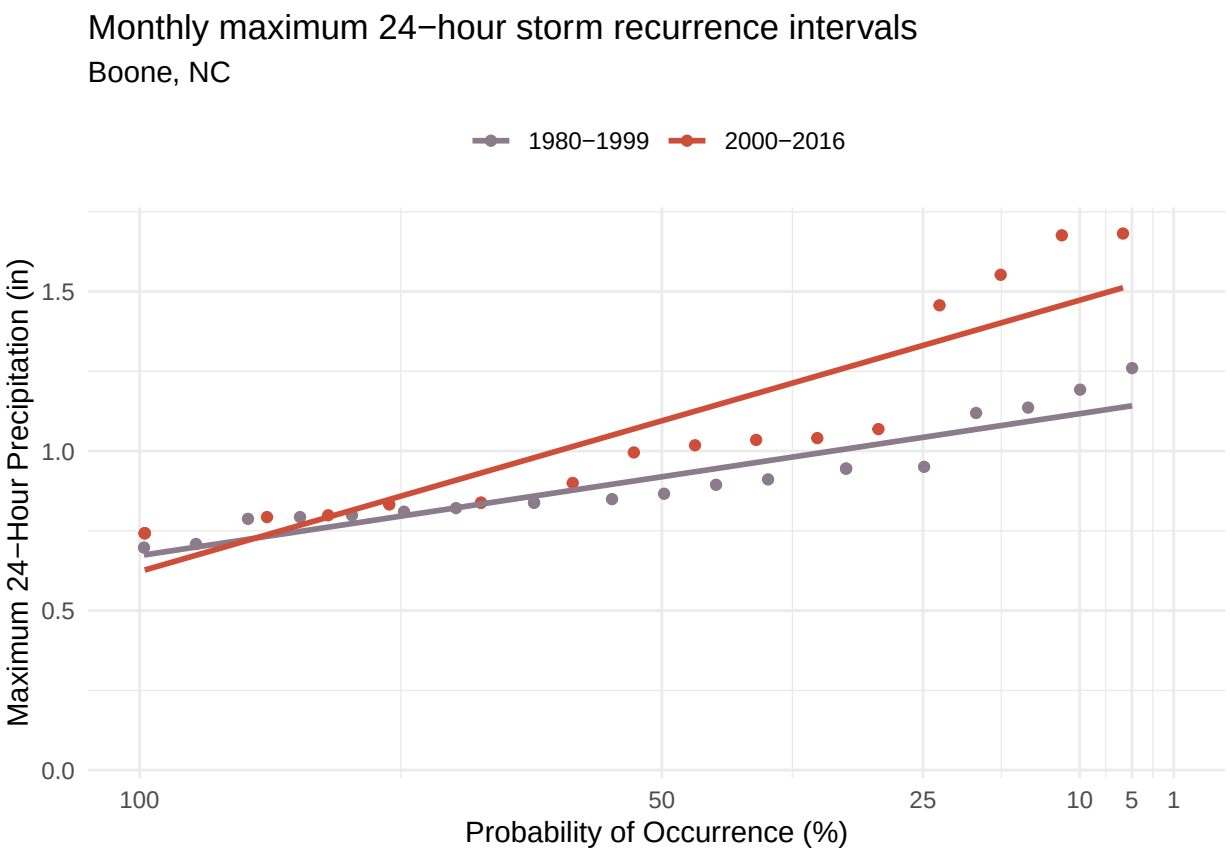

Figure 1: Boone 24-hr storm events

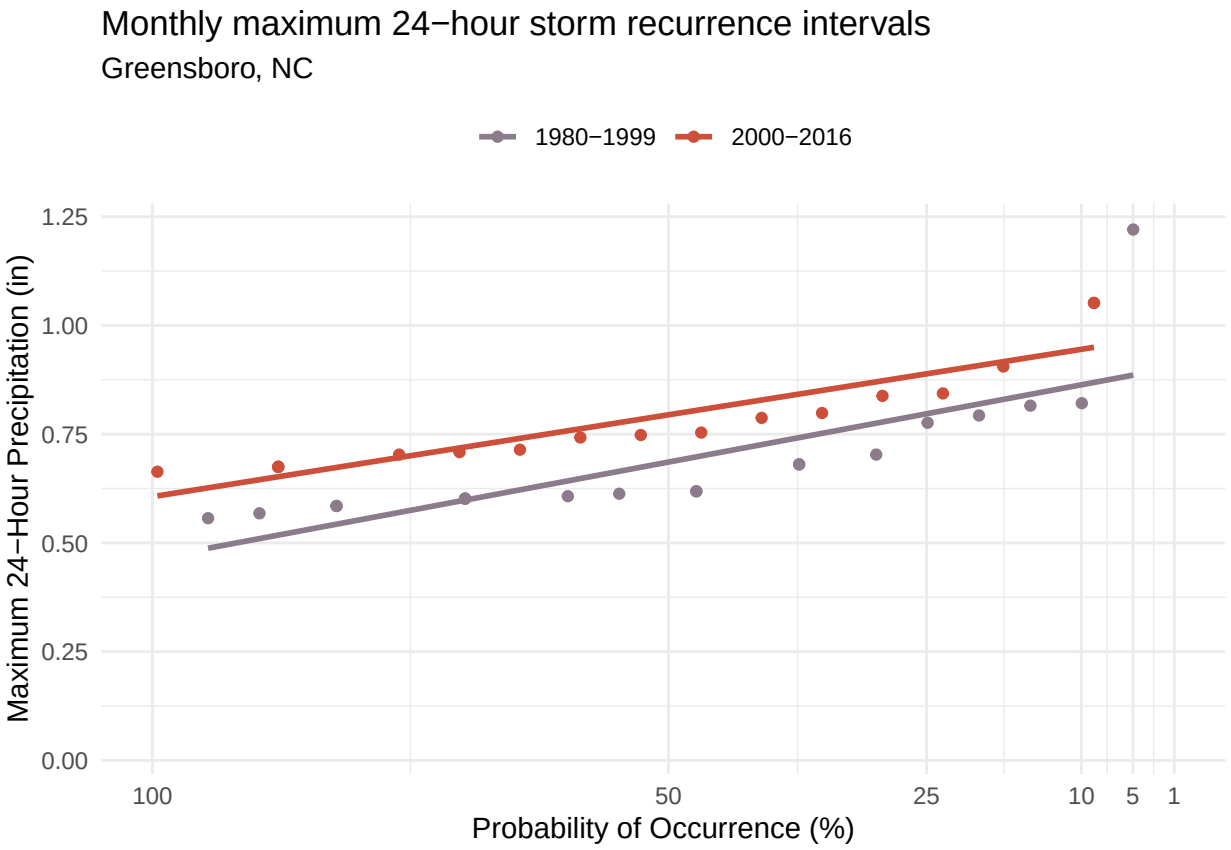

Figure 2: Greensboro 24-hr storm events

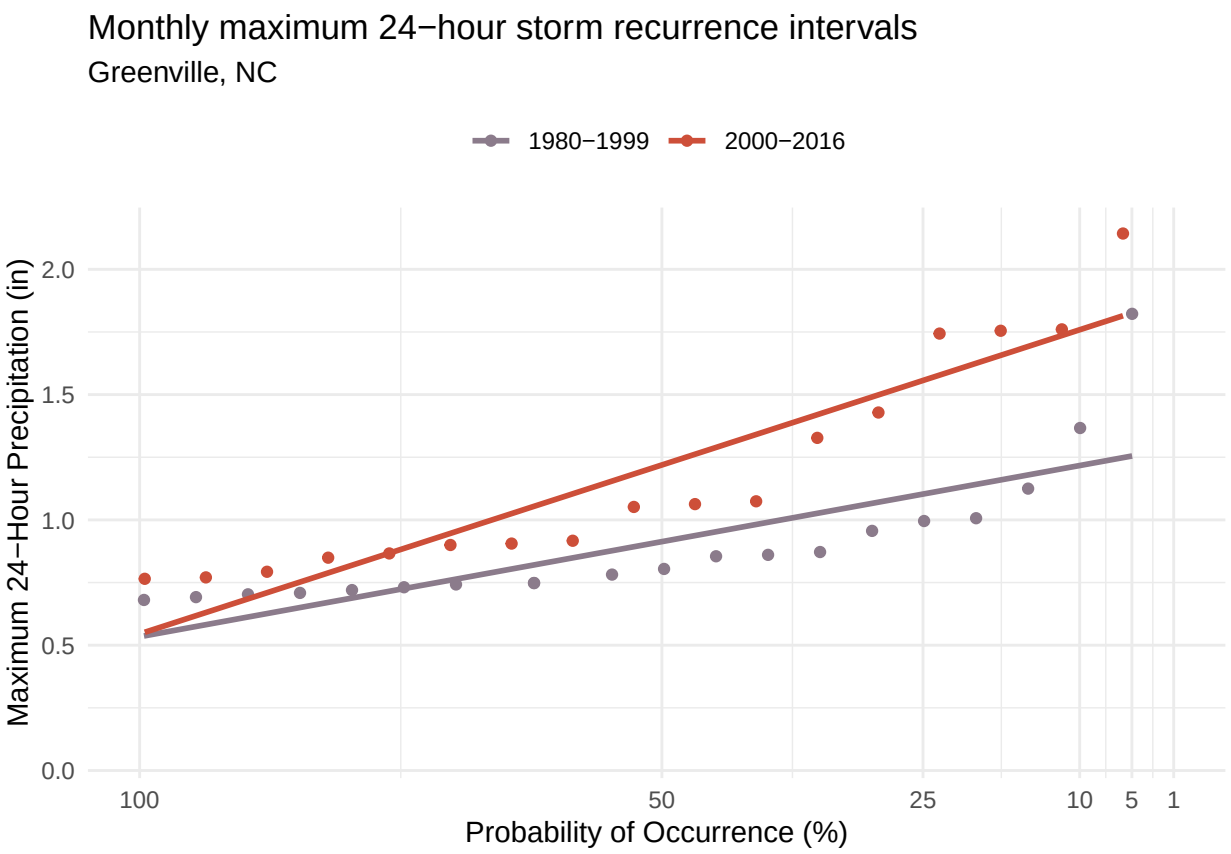

Figure 3: Greenville 24-hr storm events

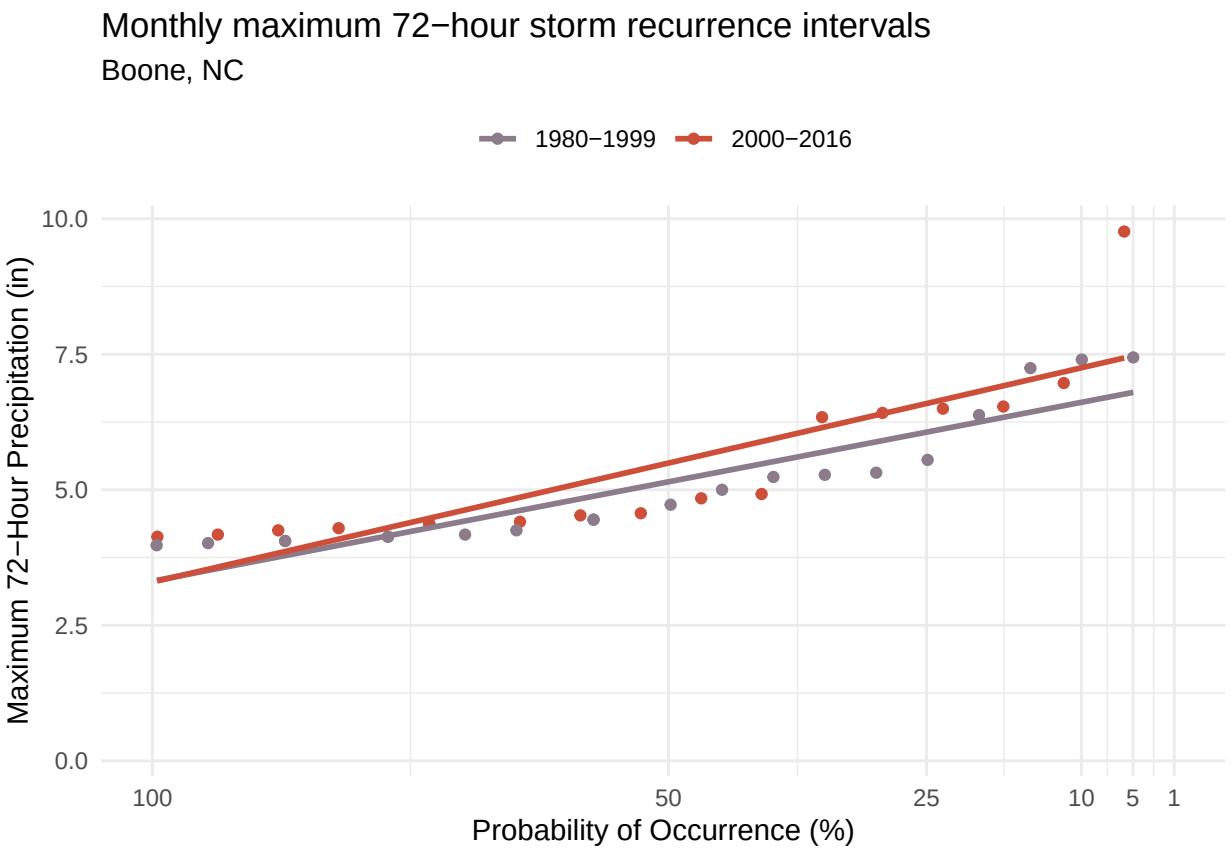

Figure 4: Boone 72-hr storm events

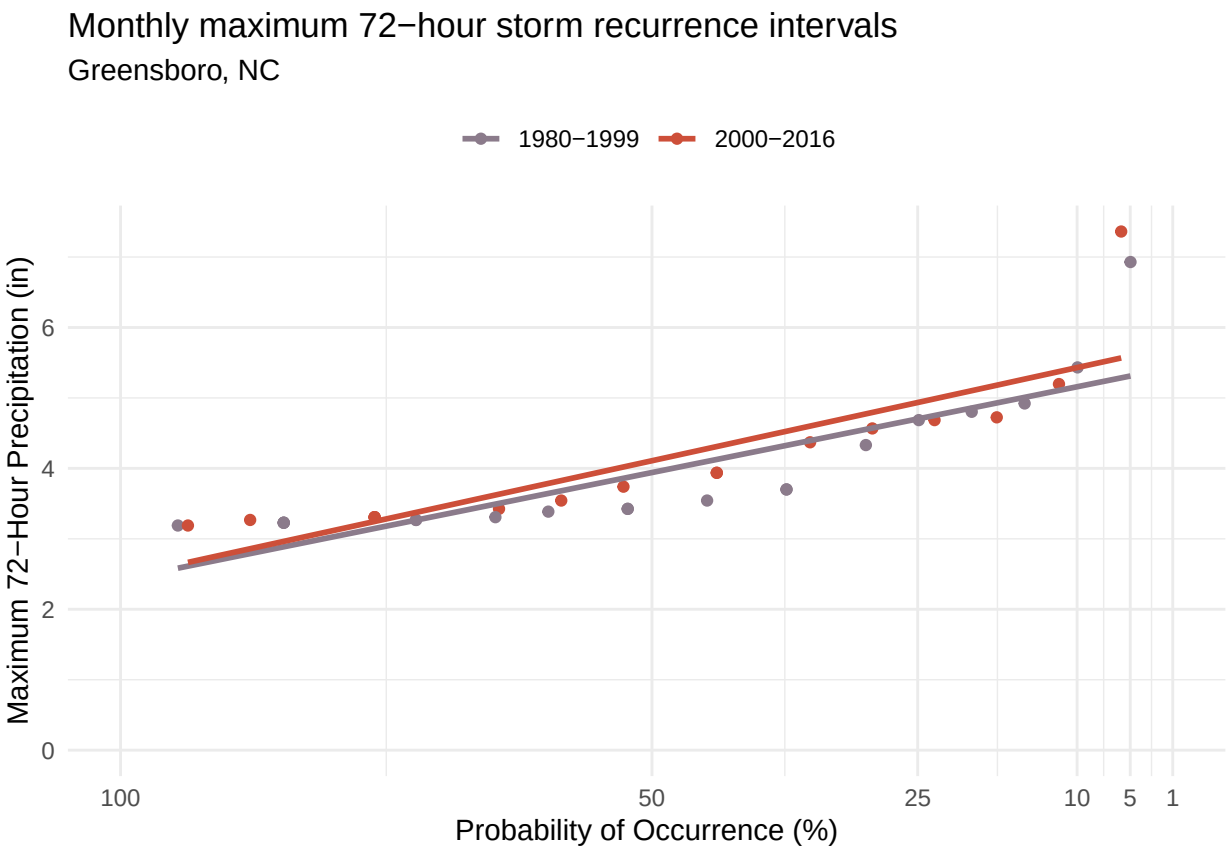

Figure 5: Greensboro 72-hr storm events

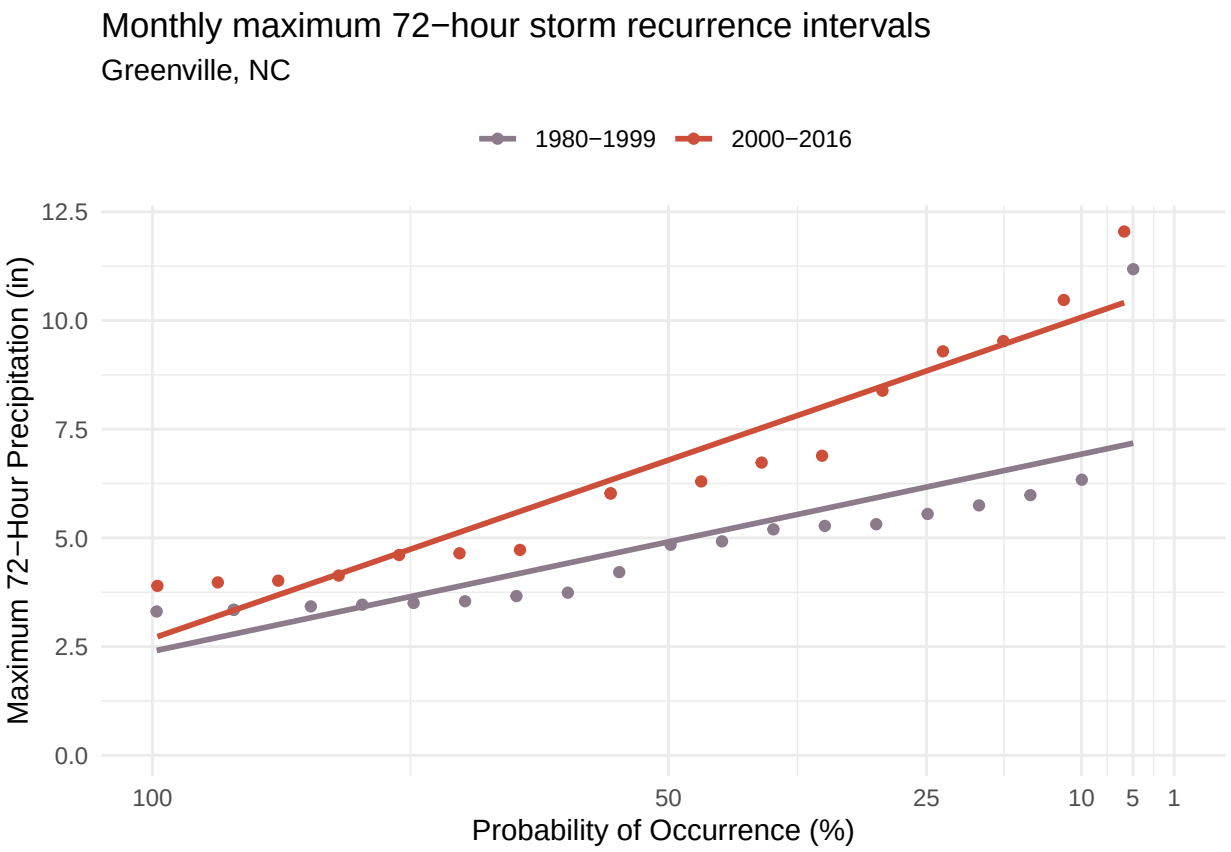

Figure 6: Greenville 72-hr storm events

distributions to extract the depth of precipitation for 10, 25, 50, and 100 year flood events for 24-hr and 72-hr events in each city for the two time periods, as seen in the tables below:

Table 1: Precipitation frequency estimates (in) for Boone, NC - 1980-1999

Duration	10 Year Flood	25 Year Flood	50 Year Flood	100 Year Flood
24-hr	1.20	1.4	1.54	1.69
72-hr	6.94	8.1	8.98	9.87

Table 2: Precipitation frequency estimates (in) for Boone, NC - 2000-2016

Duration	10 Year Flood	25 Year Flood	50 Year Flood	100 Year Flood
24-hr	1.46	1.70	1.89	2.08
72-hr	7.44	8.71	9.66	10.62

Table 3: Precipitation frequency estimates (in) for Greensboro, NC - 1980-1999

Duration	10 Year Flood	25 Year Flood	50 Year Flood	100 Year Flood
24-hr	0.96	1.12	1.23	1.35
72-hr	5.41	6.30	6.98	7.66

Table 4: Precipitation frequency estimates (in) for Greensboro, NC - 2000-2016

Duration	10 Year Flood	25 Year Flood	50 Year Flood	100 Year Flood
24-hr	1.08	1.25	1.39	1.52
72-hr	5.56	6.50	7.20	7.91

Table 5: Precipitation frequency estimates (in) for Greenville, NC - 1980-1999

Duration	10 Year Flood	25 Year Flood	50 Year Flood	100 Year Flood
24-hr	1.2	1.40	1.56	1.71
72-hr	6.5	7.62	8.46	9.31

Table 6: Precipitation frequency estimates (in) for Greenville, NC - 2000-2016

Duration	10 Year Flood	25 Year Flood	50 Year Flood	100 Year Flood
24-hr	1.55	1.82	2.03	2.24
72-hr	8.69	10.27	11.46	12.66

Changes in flood events over time

After getting the precipitation frequency estimates for 24-hr and 72-hr events for 10 year, 25 year, 50 year, and 100 year return intervals, we examined what the maximum monthly 24-hr and 72-hr events were from 1980-1999 and from 2000-2016 in each city. The purpose of this was to see if 25 year flood events (what we are assuming the infrastructure was designed for at each campus in 1999) are becoming more frequent or changing seasons from hurricane (July-October) to frontal (January-June). We counted how many times the maximum 24-hr and 72-hr 25 year flood events were occurring in each month pre-2000 and post-2000.

Table 7: Change in 25-year flood events pre-2000 and post-2000 for Boone, NC

Season	Event	1980-1999	2000-2016
Hurricane	24-hr 25-year event	0	4
	72-hr 25-year event	0	1
Frontal	24-hr 25-year event	0	0
	72-hr 25-year event	0	0

Table 8: Change in 25-year flood events pre-2000 and post-2000 for Greensboro, NC

Season	Event	1980-1999	2000-2016
Hurricane	24-hr 25-year event	1	0
	72-hr 25-year event	1	1
Frontal	24-hr 25-year event	0	0
	72-hr 25-year event	0	0

Table 9: Change in 25-year flood events pre-2000 and post-2000 for Greenville, NC

Season	Event	1980-1999	2000-2016
Hurricane	24-hr 25-year event	1	5
	72-hr 25-year event	1	5
Frontal	24-hr 25-year event	0	0
	72-hr 25-year event	0	0

25-year flood events during hurricane season have increased in frequency in Boone and Greenville since 2000. 25-year flood events in Greensboro have not increased in frequency. The results from Greensboro made us want to take a deeper dive into the data. We explored the raw data and found frequency of events greater than a 10 year flood event are happening at the same frequency in hurricane and frontal seasons pre- and post-2000 in Greensboro. Additionally, the average magnitude of these events is not increasing.

Hours spent working

Emma Kaufman: 20 hours Sarah Sussman: 13 hours Mark Lamendola: 10 hours