TOWN OF CARRBORO

NORTH CAROLINA

STORMWATER UTILITY

To: **David Andrews, Town Manager**
Mayor and Board of Aldermen
Stormwater Advisory Commission

From: **Randy Dodd, Stormwater Utility Manager**

Cc: **Joe Guckavan, Public Works Director**
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Marty Roupe, Zoning Administrator
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Josh Dalton, Sungate Engineering
Bill Roark, McGill & Assoc.

Date: **November 6, 2018**

Subject: **Rainfall and Runoff in Recent Storms**

Background and Summary

The purpose of this memorandum is to respond to interest expressed by the Board of Aldermen as part of the Sanderway CUP review about the relationship of rainfall and runoff in recent storms to design storms. An assessment using data from local stream and precipitation gages, historical and current rainfall depth and duration data, and a flood elevation observation is provided. The Town has experienced several 10 and 25 year recurrence interval events in the past 25 years, but does not appear to have experienced larger events, with the possible exception of Florence, which has indications of closer to a 50 year recurrence event. This observation should be tempered by limitations in available data and analyses.

Information

According to information referenced in a study by the UNC Institute for the Environment[1], the amount of rain falling during heavy downpours in the Southeast has increased by 27%, with a steady increase in North Carolina from 1950 until 2020 (Walsh et al., 2014[2]). Durham is among the cities that have experienced the greatest increase in the number of heavy downpours (129%) (Climate Central, 2015[3]). While there is considerable anecdotal and subjective evidence of more intense and frequent events in Carrboro, especially in the past five years, it is a complex undertaking, and beyond

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[1] http://www.orangecountync.gov/DocumentCenter/View/1645/Report-Incorporating-Climate-Change-into-Hazard-Mitigation-PDF?bidId=

[2] Walsh, J., D. Wuebbles, K. Hayhoe, J. Kossin, K. Kunkel, G. Stephens, P. Thorne, R. Vose, M. Wehner, J. Willis, D. Anderson, S. Doney, R. Feely, P. Hennon, V. Kharin, T. Knutson, F. Landerer, T. Lenton, J. Kennedy, and R. Somerville. (2014). Ch. 2: Our Changing Climate. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 19-67. doi:10.7930/J0KW5CXT.

[3] http://www.climatecentral.org/news/across-us-heaviest-downpours-on-the-rise-18989

the scope of this memo, to attempt to specifically quantify the strength of the climate change "signal" relative to random fluctuations ("noise"), how much/rapid of a trend in increasing frequency/intensity may be occurring in Carrboro, and factors besides climate change that may be contributing to the flooding impacts in Carrboro. The following discussion does attempt to more qualitatively assess the pattern of heavy rain and runoff events, using locally relevant data.

By way of additional introduction and context for the assessment that follows, it is important to consider how rainfall/runoff information is communicated. The language that is sometimes used when referring to large rain and runoff events can be subject to misinterpretation. For example, "This storm has resulted in a 100-year flood…." can lead to confusion because some may interpret this as meaning that the creek/river reached a peak stage (height) that will happen only once every 100 years. When similar storm events happen repeatedly within a shorter amount of time than the recurrence interval, there is an understandable disconnect. Hydrologists tend to avoid terms like "100-year flood" because a hydrologist would rather describe this event as a flood having a 100-year recurrence interval (see Table 1). What this means is that a flood of this magnitude has a 1 percent chance of happening in any given year. While the probability is slim, just because it rained 7.6 inches over a 24 hour period, or a creek reached a certain flood stage, does not necessarily mean that level of rain or stage has a lesser (or greater) chance of happening again in the same year, or soon thereafter.

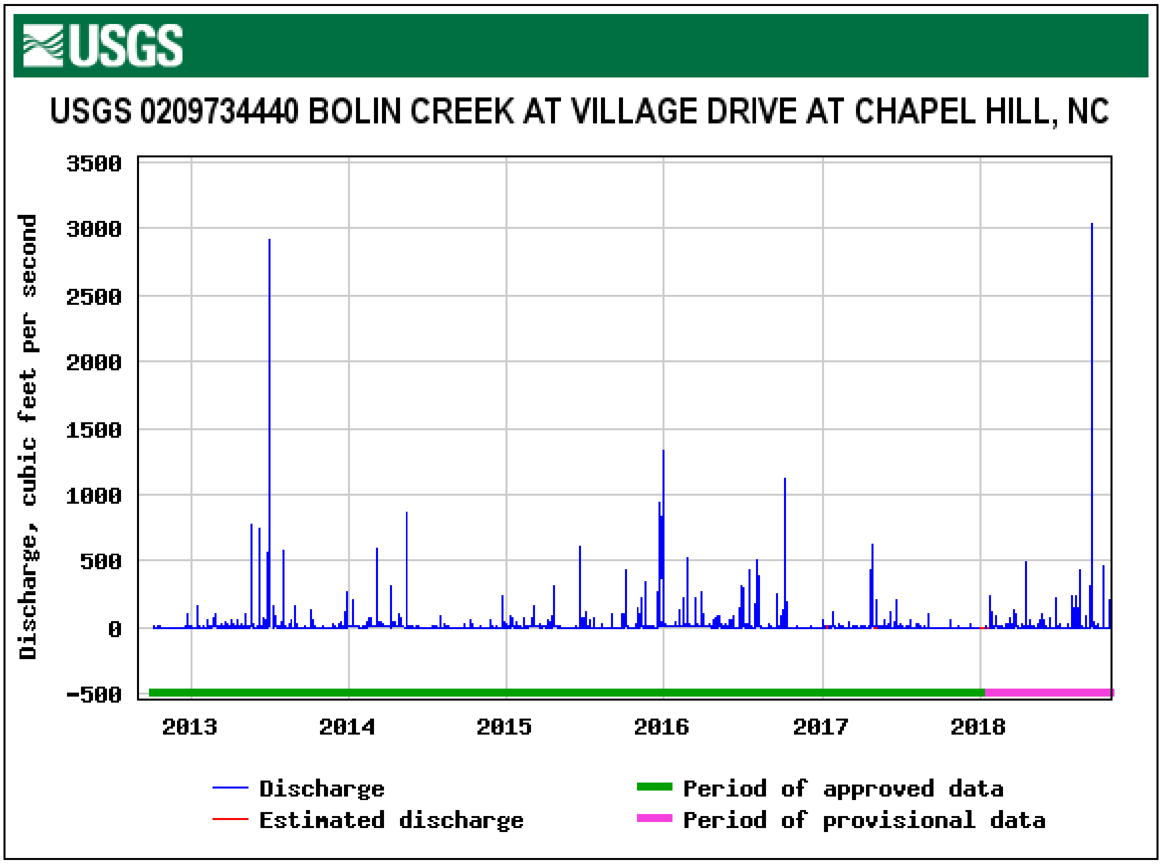
Table 1: Cross Reference Between Recurrence Interval, Probabilities, and % Chance[1]

Recurrence Interval (Years)	Probability of Occurrence in any Given Year	% Chance of Occurrence in any Given Year
100	1 in 100	1%
50	1 in 50	2%
25	1 in 25	4%
10	1 in 10	10%
5	1 in 5	20%
2	1 in 2	50%

Streamflow Based Storm Event Observations

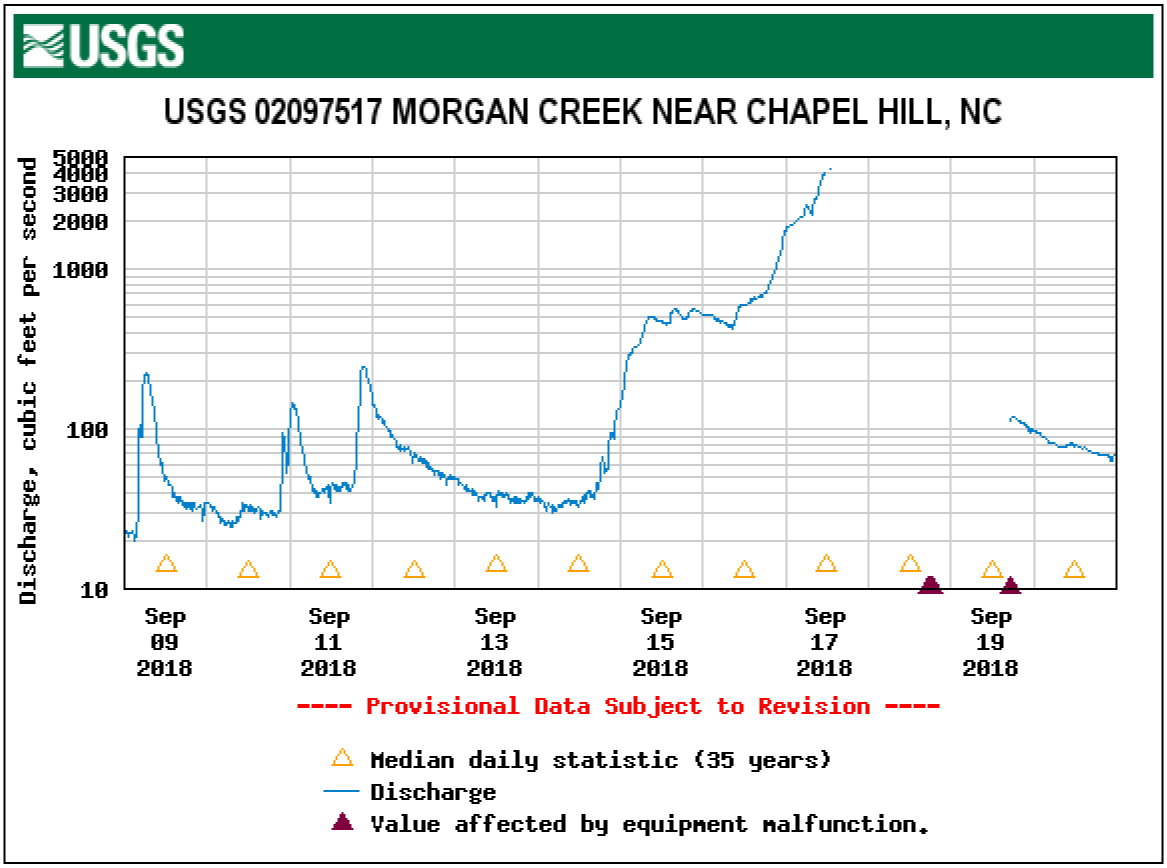
There are currently two (continuously recording) urban stream gages measuring stream flow near Carrboro. There is a gage that has been operating since 1985 on Morgan Creek (near the NC Botanical Gardens and golf course (02097517) and a second gage on Bolin Creek at the corner of Village Dr. and Umstead Dr.; (0209734440) that was installed in 2012. Since the Bolin Creek gage has a relatively short recording period, it is not possible to develop longer term peak flow statistics to relate recent storm events to design storms. The Bolin gage shows that the June, 2013 and September 17, 2018 events were of similar magnitude and had more than twice the flow of any other peak flow since the gage was installed about six years ago. These two events also seem to have resulted in similar impacts/flood elevations for residences along Toms Creek

Figure 1: Bolin Creek Streamflow 2013-2018



From the stream gage on Morgan Creek, the provisional data show that stream flow from Florence exceeded 4000 cfs on 9/17/18 (Figure 2), which puts it at about a 2-4% probability (in a given year) storm, in the realm of Hurricane Fran (Figures 3). Note that the gage was not able to actually record the peak and recession of discharge after the storm passed.

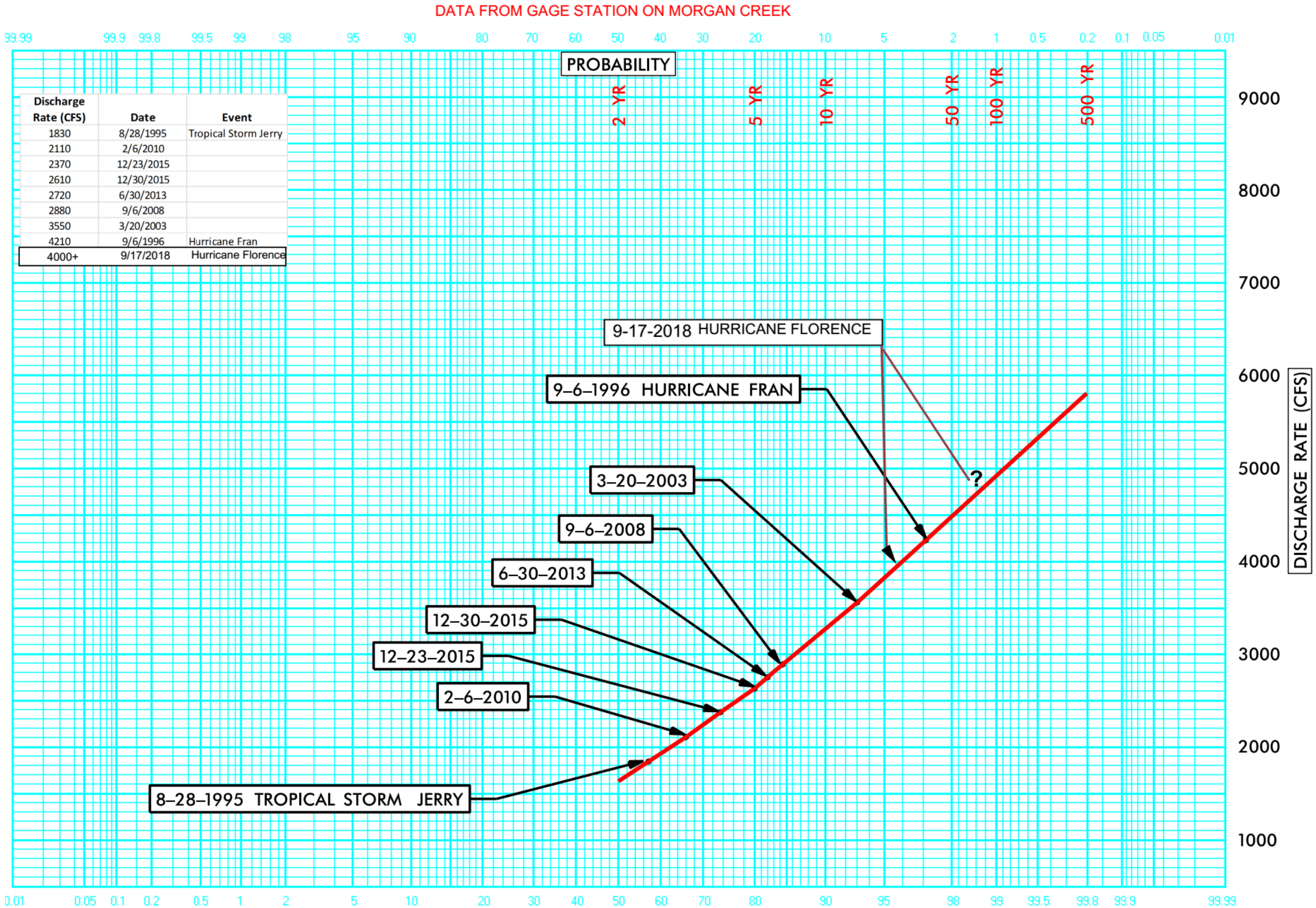
Figure 2: Morgan Creek Streamflow September 2018



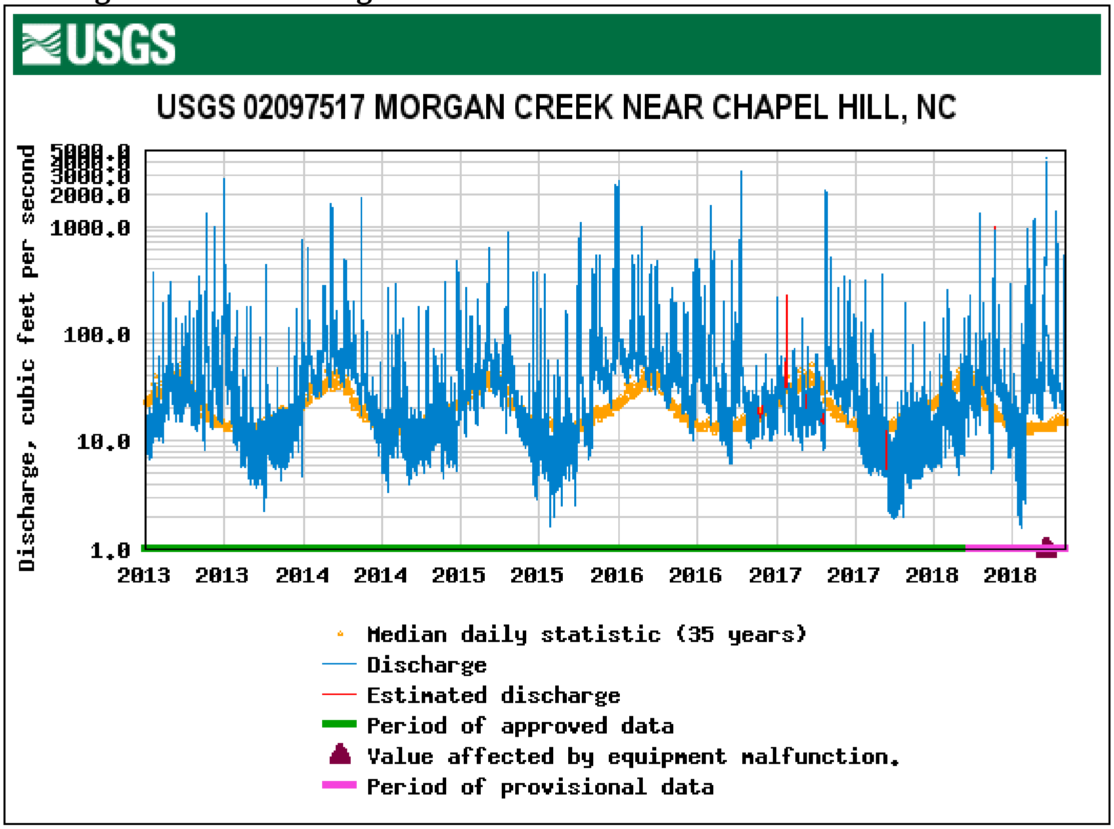
The longer term stream flow record for this Morgan Creek gage can be used to assess the magnitude of Florence relative to other high flow events (Figures 4 and 5.) From Figure 4 and as with the Bolin Creek gage, it is apparent that Florence was the largest event since 2013, with 4 other events during this time frame having at least 50% of the peak flow as was measured during Florence. Looking back to when the gage began operation, note that there were no flow events greater than 2000 cfs between 2000 and early 2013, although there were 4 such events between 1985 and 2000. This "lull" in higher flow events between two periods with more of these larger magnitude events could have the effect of magnifying the perception of a recent increase that does not fully recognize the longer term record.

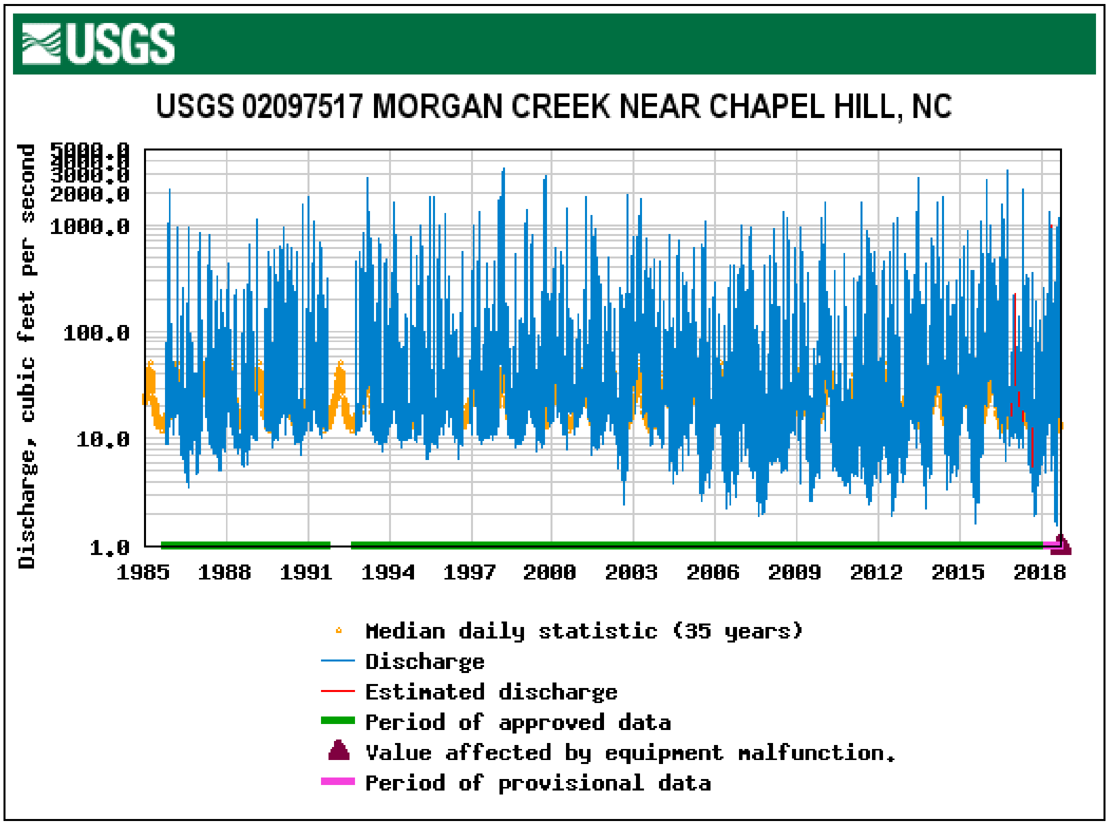
Figure 3: Morgan Creek 1995-2018 Storm Events Compared to Design Storms

(Modified from Sungate Report in 2016)



Figures 4 and 5: Morgan Creek Streamflow 2013-2018 and 1985 to 2018





Rainfall Based Storm Event Observations

Another means of studying storm events is to compare rainfall in specific events (Table 2) to the rainfall amounts for design storms of various durations and recurrence intervals (Table 3).

Table 2: A Comparison of Stream flow and Rainfall in Recent Events
(Modified from Sungate Report in 2016)

	GAGE HEIGHT	DISCHARGE	RAINFALL*	RECURRENCE**
8/28/95 T.S Jerry	11.8’	1830 cfs	5.5”	>2-Year
2/06/10	12.6’	2110 cfs	1.9”	>2-Year
12/23/15	13.1’	2370 cfs	2.4”	<5-Year
12/30/15	13.6’	2610 cfs	2.5”	5-Year
6/30/13	13.8’	2720 cfs	2.4”	>5-Year
9/06/08	14.1	2880 cfs	4.5”	>5-Year
3/20/03	15.2	3550 cfs	2.2”	>10-Year
9/06/96 Fran	16.2	4210 cfs	8.8”	<50-Year
9/17/18 Florence	>16’	>4000 cfs	9.7” (4 days)	<50-Year

*Rainfall information shown in Table 2 obtained from rain gages at Horace Williams Airport in Chapel Hill, NC and RDU International Airport in Raleigh, NC.
** Based on stream gage

Table 3: Rainfall Depth Duration Values for Carrboro[4,5]

	Rainfall Depth (Inches) For Design Storm Recurrence Interval (Years)									
Duration	**1 yr**	**2 yr**	**5 yr**	**10 yr**	**25 yr**	**50 yr**	**100 yr**	**200 yr**	**500 yr**	**1000 yr**
60-min	1.4	1.69	2.06	2.35	2.69	2.95	3.19	3.43	3.72	3.95
6-hr	2.15	2.59	3.2	3.71	4.37	4.91	5.46	6.02	6.78	7.42
12-hr	2.54	3.06	3.81	4.44	5.28	5.98	6.71	7.47	8.52	9.42
24-hr	2.96	3.58	4.47	5.17	6.11	6.86	7.62	8.4	9.48	10.3

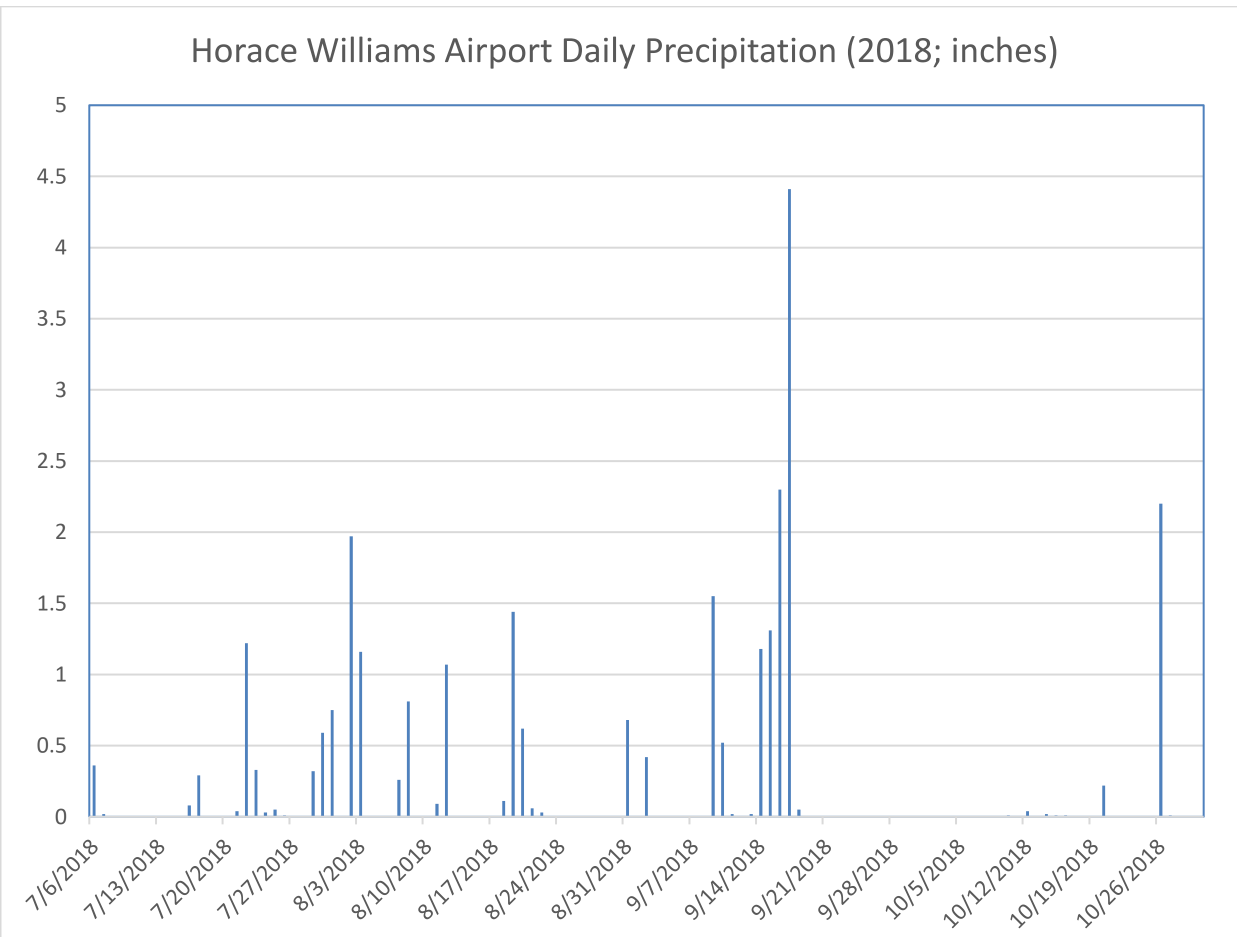
One interesting observation from this data is that the frequency or recurrence interval for the different events can be assigned to different design storms depending on whether the stream flow

[4] (From NOAA Atlas 14: https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_printpage.html?lat=35.9233&lon=-79.0823&data=depth&units=english&series=pds Note that the values shown have not changed appreciably since 1995, and in fact have experienced a small (generally < 5%) decrease during this time frame.
[5] From the Horace Williams airport rain gage (daily summary), there was one day (June 30, 2013) from July, 1999 up to the present at or above the 10 year 24 hour storm, and none at or above the 25 year storm. However, as discussed in the text, 24 hour storm events can cross over two days, so there are likely several more 10 and 25 year events over the past 25 years.

or rainfall is the basis. It is also helpful to note that the June, 2013 storm came in at about a 5 year storm when compared to the Morgan gage and about a 10 year event based on rainfall, although the impacts for Toms Creek properties were greater than most of the other storms, and of similar magnitude to Florence.

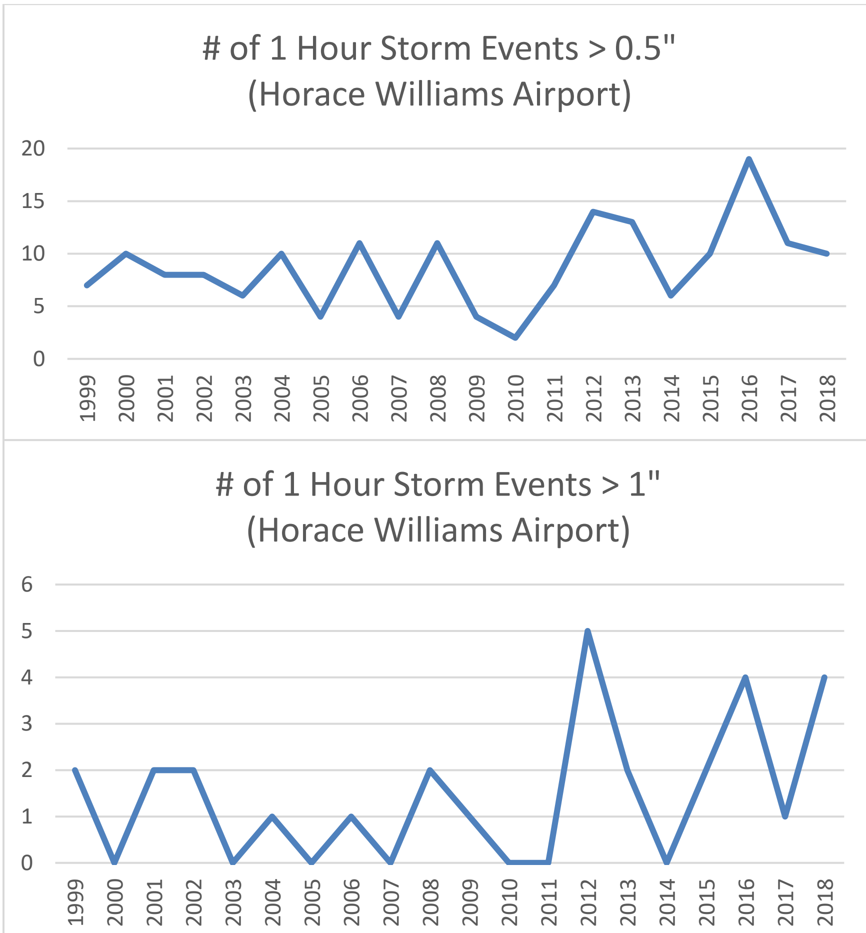
Another important consideration is that it is possible that a simple 24 hour, or total storm event, precipitation statistic may not be an adequate metric to fully understand the potential storm impact. Rainfall intensity (inches/hour) is one way to get a handle on this issue, as is a closer examination of rainfall over time around a given storm event. For example, Florence resulted in 4 days of rain in Carrboro, and a total precipitation of close to 9 inches that was preceded several days before by a smaller event (Figure 6). If one were to simply look at 24 hour rainfall, there was no single day with more than 4.5 inches of rain. However, about 3 inches of rain fell in about 3 hours at the tail end of Florence, when the ground was completely saturated. The combination of steady rain and saturated soils and increasing and excessive tail end intensity resulted in an event that certainly exceeded what would have otherwise been expected based strictly on 24 hour rainfall statistics.

Figure 6: Precipitation at Horace Williams Airport in Past 3 Months



Local hourly rainfall data from 1999-2018 were also obtained since a focus on longer duration (daily) values may miss patterns or changes in rainfall intensity. A comparison was done to see the number of times per year that hourly rainfall exceeded 0.5” and 1” (Figures 7a,b)[6]. These data suggest a trend towards more frequent shorter duration downpours in recent years.

Figures 7a,b



<u>Flood Elevation Based Storm Event Observations</u>

Another way to study storm events is to attempt to measure the flood elevation when a creek tops its bank and spills out into the floodplain. The elevation of the high water mark can be compared to mapped flood elevations, e.g., for the 1% (100-year) and 0.2% (500-year) flood elevations. These flood elevations are regularly modeled, mapped and updated for regulated floodplains draining at least 0.5 square miles.

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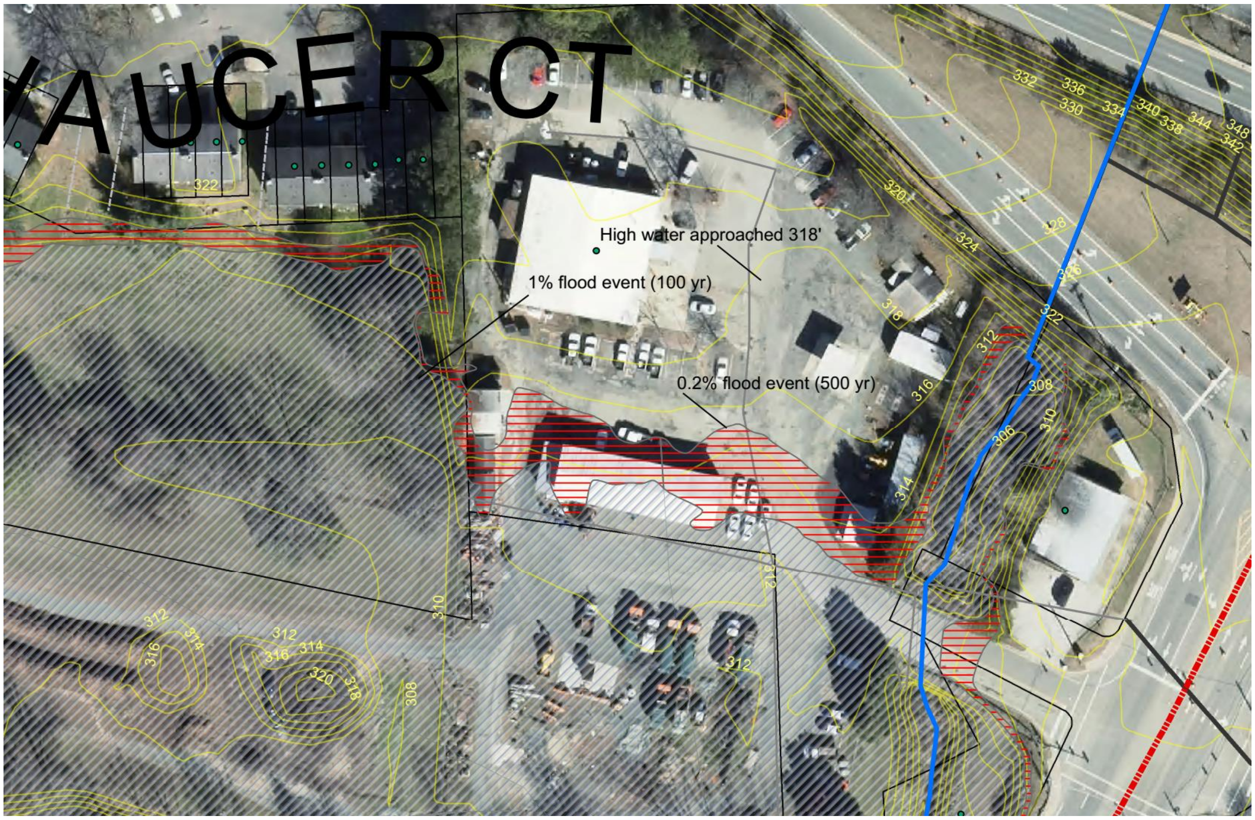
[6] Note that none of the 1 hour events during this time period reached the level of even a 2 year storm (1.69”). These events in and of themselves are indicative of more localized, nuisance flooding rather than causing larger streams to come out of their banks.

A more thorough attempt to capture the high water marks from Florence has not (yet) been completed, although one specific observation can be passed on. At the Public Works facility, Florence resulted in a flood elevation that exceeded any observed flood elevation by Public Works staff, and also exceeded both the 1% and 0.2% probability elevations (Figure 7). This happened in spite the fact that significant flood impacts were not reported for the Rocky Brook neighborhood across NC 54 bypass, a regularly flood prone area, during Florence.

Figure 7: Map of Flooding During Florence at Carrboro Public Works



Summary/Additional Observations

A couple of additional/summary points are important to note:

1) Rainfall recurrence intervals are based on both the magnitude and the duration of a rainfall event, whereas streamflow recurrence intervals are based solely on the magnitude of the peak flow. It is helpful to consider both in determining the magnitude of a given storm.
2) The USGS has found that the effects of urban development on peak flows is generally greater for low-recurrence (e.g., 2-10 year) interval events than for high-recurrence interval floods, (e.g., 25-100 year) events.[7] During these larger floods, the soil is saturated and does not have the capacity to absorb additional rainfall. Under these conditions, the landscape is behaving as an impervious surface, and essentially all of the rain that falls runs off immediately.
3) Confounding factors besides development/land use include:
    a. Local/site scale variability and deviation from what is occurring at the available gages;
        i. Flow rates in different sized drainage basins vary based on the duration of the storm. Larger drainage basins have higher times of concentration and will experience larger flow rates in longer duration storms. Small drainage basins have smaller times of concentration and may experience larger flow rates in shorter duration storms (intense thunderstorms);
4) To reiterate, Florence presents a good example of the need to look beyond simple metrics since it was a 4 day event, with steady but not extraordinary rain for the first three days, and ending in several hours of intense rain. The degree of flooding impacts therefore would not be predicted by a simple summary statistic such as the 24 hour rain event.
5) Data limitations and different data sources, confounding factors, and different insights from different approaches to analysis lead both to some uncertainty and a need for careful interpretation and looking at storm event assessment using these multiple tools.
6) There has been in an uptick in high flow events in larger streams since 2013 relative to the preceding decade, but these events are relatively similar to what was experienced in the late 20th century.
7) Both regional studies and a local analysis of hourly rainfall data confirm that the intensity of shorter duration storm events has been increasing.

Recommendation

Staff recommend that the Board of Aldermen and Stormwater Advisory Commission receive this memo.

[7] https://water.usgs.gov/edu/100yearflood.html