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Technical Notes: Magnitude and Return Period of 2004 Hurricane Rainfall in Florida

Abstract
The 2004 hurricane season was one of the worst on record for the state of Florida. Four separate storms (Hurricanes / Tropical Storms) made landfall on or near the state. These storms included: Charley (August 10 – 15), Frances (August 26 – September 6), Ivan (September 3 - 18), and Jeanne (September 14 – 27). The impact of the storms resulted in billions of dollars in damage and widespread flooding. Cumulative rainfall is reviewed for two storms with similar paths, Frances and Jeanne. Using hourly rainfall data, the maximum cumulative rainfall amounts were determined for various rainfall durations (1, 2, 6, 12, 24, and 48-hour) and return periods (1, 2, 5, 10, 25, 50, and 100-year) were assigned to the rainfall durations. Maximum cumulative rainfall, from Frances and Jeanne, for the 24-hour period was then compared to the synthetic 100-year return period design storm [Natural Resources Conservation Service (NRCS), Type II distribution] used in the region for floodplain determination and detention design. The results show that 24-hour hurricane rainfall exceeded the 100-year return period design storm and that the shape of the cumulative distribution of the hurricane rainfall is somewhat similar to the shape of the synthetic rainfall distribution.

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Introduction

During the 2004 hurricane season, four separate storms (Charley, Frances, Ivan, and Jeanne) made landfall on or near the state of Florida. This resulted in billions of dollars in damage and widespread flooding. Storms Frances and Jeanne moved along similar paths (Figure 1). Each made landfall on the Atlantic coast of Florida, north of the Miami-Dade metropolitan area. After landfall, they moved in a westward path before turning north and moving into southern Georgia. The objective of this study is to evaluate rainfall from Hurricanes Frances and Jeanne. Using hourly rainfall data, the maximum cumulative rainfall amounts were determined for various rainfall durations (1, 2, 6, 12, 24, and 48-hour) and next, return periods (1, 2, 5, 10, 25, 50, and 100-year) were determined. The maximum cumulative rainfall for the 24-hour period was then compared to the synthetic 100-year (and 25-year) return period design storms [Natural Resources Conservation Service (NRCS), Type II distribution] used in the region for floodplain determination and detention design.

The Suwannee River originates in the Okefenokee Swamp in southeastern Georgia (Figure 1). The river has four major tributaries – the Alapaha, Little, Santa Fe, and Withlacoochee Rivers. Frances' storm track was immediately west of the watershed while Jeanne's storm track was directly over the watershed. The Suwannee River Water Management District (SRWMD) is one of five water management districts in the state of Florida. The SRWMD is the primary surface water regulatory agency of this region. It is responsible for both water quality and water quantity of the river system. The SRWMD has stringent stormwater regulations with regards to water quantity discharges (rate and volume) into the river system. The region has experienced significant growth and development during the past twenty years. New development is required to detain water such that the rate of discharge (and, in some cases, volume) from the developed site is less than pre-development runoff rate (volume). Generally, detention ponds are created to attenuate stormwater runoff to meet this requirement.

A synthetic rainfall distribution is used to develop hydrographs and these hydrographs are then used in the design of detention structures (e.g., ponds). The NRCS (formerly, Soil Conservation Service or SCS) Type II rainfall distribution is applicable to this region (USDA, 1986). The Type II rainfall distribution is a cumulative distribution with a 24-hour duration. In this region of Florida, the 100-year 24-hour cumulative rainfall amount is approximately 27.9 cm (11 inches), while the 25-year, 24-hour cumulative rainfall amount is approximately 20.3 cm (8 inches). These values are multiplied times the dimensionless cumulative SCS Type II distribution to determine the 100-year and 25-year rainfall distributions, respectively.

Data and Results

Hourly rainfall data were obtained from the SRWMD for 30 rainfall stations (Figure 1). For both Frances and Jeanne, the maximum cumulative rainfalls were determined for each rainfall station for the 1, 2, 6, 12, 24, and 48-hour durations. The maximum cumulative rainfall depths, for all durations and both storms are provided in Table 1.

Table 1. Rainfall Duration (hours), Maximum Cumulative Rainfall (cm) and Return Period (years) for Frances and Jeanne

	Frances		Jeanne	
Rainfall Duration (hours)	Maximum Cumulative Rainfall cm (inches)	Frequency (Return Period) (years)	Maximum Cumulative Rainfall cm (inches)	Frequency (Return Period) (years)
1	5.6 (2.2)	2	3.0 (1.2)	< 1
2	8.4 (3.3)	5	5.8 (2.3)	1
6	15.7 (6.2)	> 25	14.5 (5.7)	25
12	24.6 (9.7)	> 100	17.3 (6.8)	25
24	32.0 (12.6)	>100	17.5 (6.9)	10
48	40.1 (15.8)	> 100	17.5 (6.9)	> 5

Additionally, the return period, in years, is provided (NWS TP-40, 1977 and FDOT, 1987). The results reveal that for shorter duration rainfalls the return period is smaller than for the longer duration periods. During a hurricane event, 1-hour and 2-hour rainfall depths are not as intense as during convectional (or monsoon) storms. These storms typically occur in the summer season (late afternoon thunderstorms).

A more detailed analysis of the maximum cumulative rainfall, for the 24-hour duration, was performed. For both storms, the three gages that produced the maximum cumulative rainfall for the 24-hour duration were identified and compared to the SCS Type II 100-year and 25-year synthetic rainfall distributions (Figures 2 and 3). For Frances, two gages reported cumulative rainfalls greater than the 100-year return period of 27.9 cm (11 inches). Rainfall gage 271 reported a cumulative 24-hour rainfall of 32.0 cm (12.6 inches) while gage 240 reported 29.5 cm (11.6 inches). For both of these distributions, the shape was somewhat similar to the Type II distribution. The slope of the Type II distribution is steep around hour 12, representing the most intense period of rainfall. Rainfall gage(s) 271 and 240 have relatively steep slopes at 16 and 19 hours, respectively.

For Jeanne, none of the three gages exceeded the 24-hour cumulative rainfall for the 25-year return period of 20.3 cm (8 inches). While some variability was evident in the shape of the distribution for the three rainfall gages selected for Frances, this is not apparent for Jeanne. All three gages had almost identical distribution shapes. Also, the majority of rainfall occurred during an 8-hour period, from hour 4 to hour 12. After hour 12, rainfall appeared to approach zero. This could be the result of a fast moving storm.

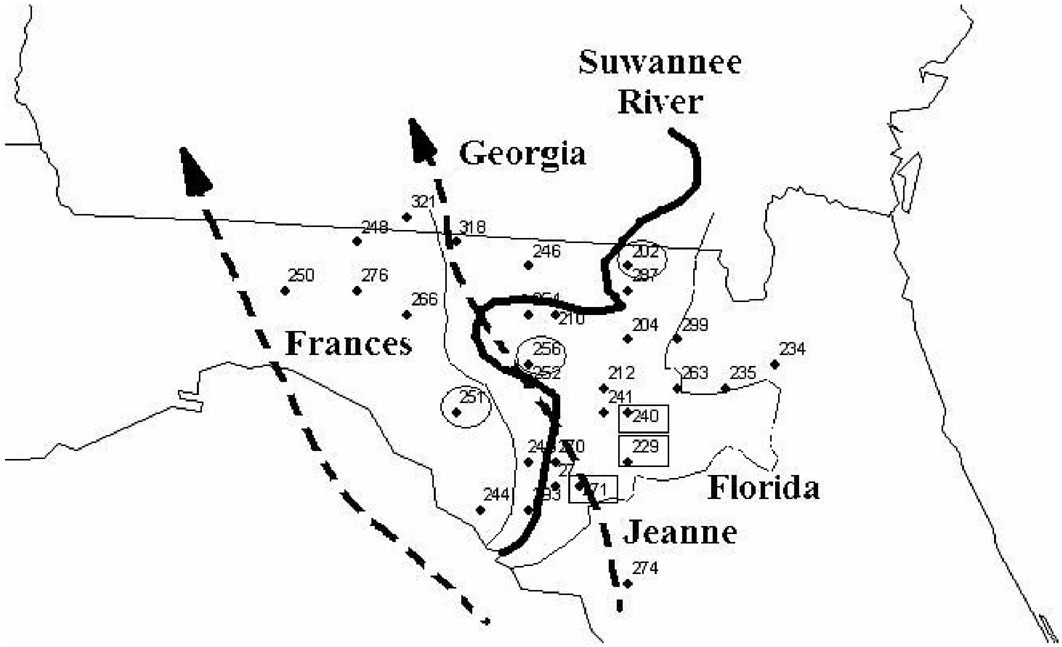

Fig. 1. Storm center path(s) for Frances and Jeanne, Suwannee River (with watershed boundaries) and Rainfall Station Locations. The stations used in the 24-hour analysis ("squares" for Frances and "circles" for Jeanne) are identified.

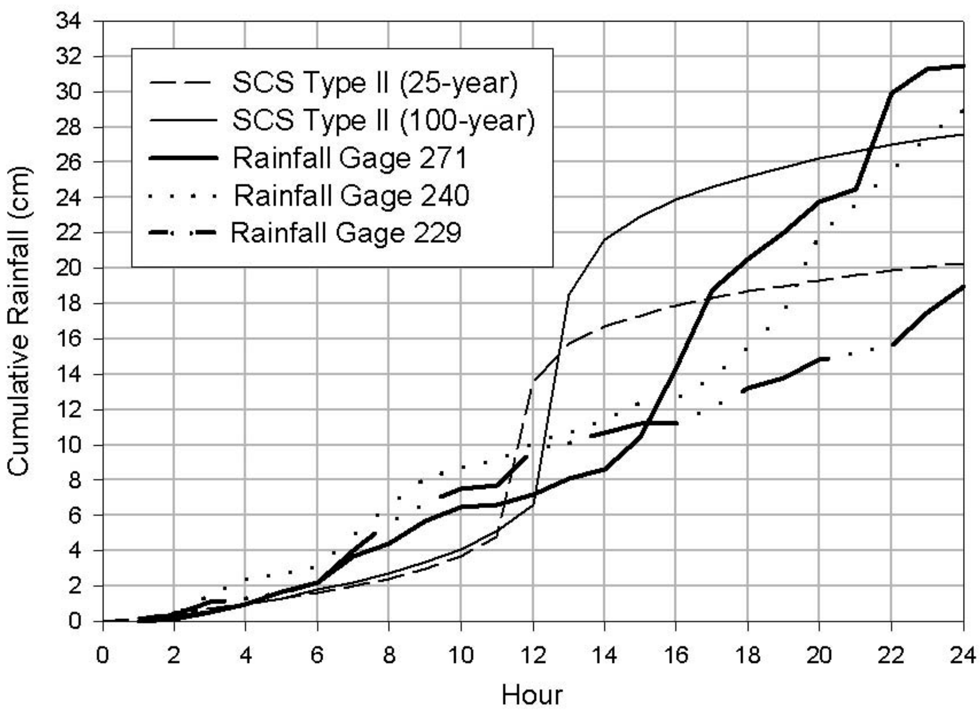

Fig. 2. NRCS/SCS Type II (100-year and 25-year) 24-hour Rainfall Distributions for Suwannee River region (USDA, 1986) and the three maximum 24-hour Cumulative Rainfall Distributions from gages for Frances

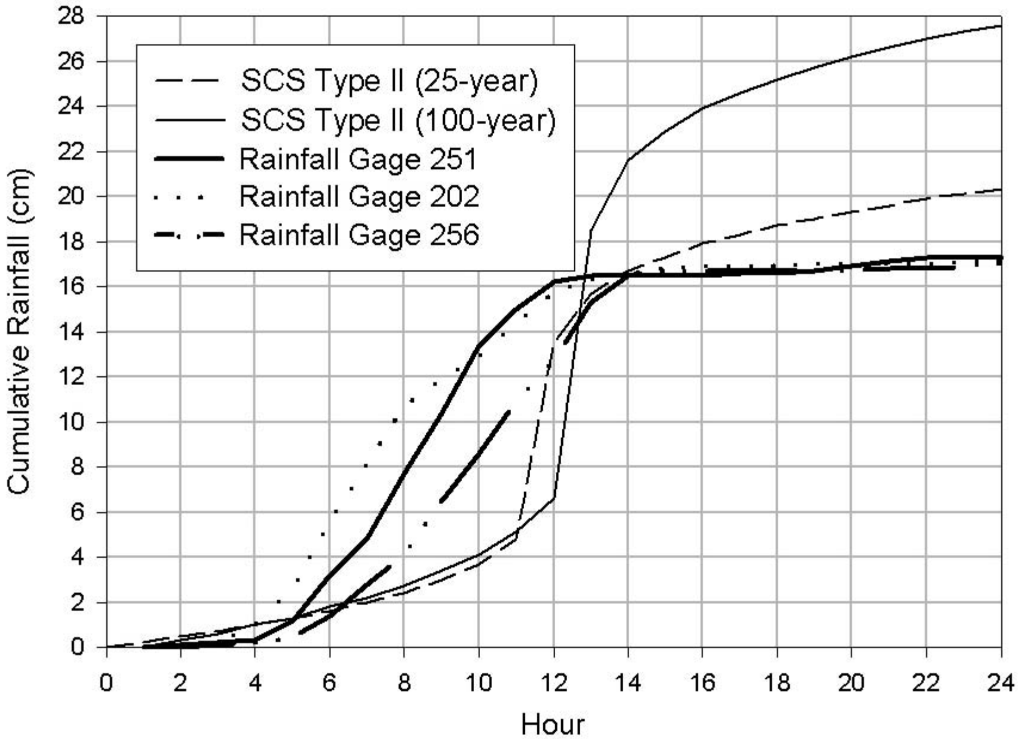

Fig. 3. NRCS/SCS Type II (100-year and 25-year) 24-hour Rainfall Distributions for Suwannee River region (USDA, 1986) and the three maximum 24-hour Cumulative Rainfall Distributions from gages for Jeanne

Conclusions

The maximum cumulative rainfall of a hurricane was analyzed for various durations. The results showed that short duration (1 or 2 hour) events, within the cumulative rainfall of the hurricane, do not have high intensities (or return periods). Convectional (summer monsoon) storms are generally short in duration and produce intense rainfall. These storms are most probably responsible for high return period, short duration events.

Based on discussions with water managers and a review of winter rainfall data, long (1-day) hurricane rainfall events generally exceed rainfall from winter frontal storm activity. However, it should be noted that Florida is a region highly influenced by the El Niño-Southern Oscillation (ENSO). Warm El Niño events typically result in increased precipitation (and streamflow) during the winter and spring seasons. Some of the largest recorded floods of the Suwannee River occurred as the result of the cumulative effects of several consecutive broad frontal-type rainfall events over the basin in March and April of 1948, March 1959, and April 1973 (Giese et al., 1996).

Rainfall magnitude (and return period) was greater for Frances than Jeanne. Rainfall depths for two rainfall gages during Frances exceeded the 100-year return period. Although numerous factors, such as storm speed, could impact this result, the increased magnitude of the rainfall was most likely due to the more westward track (with regards to the rainfall gages) of Frances' when compared to Jeanne (Figure 1). Cyclonic storms in the northern hemisphere rotate counter clockwise. Typically, the most severe activity is along the northeast quadrant of the storm. For Frances, the northeast quadrant passed directly over the gage area while Jeanne's northeast quadrant was slightly east of the gage area.

Future research could include obtaining rainfall data from other stations throughout the state of Florida affected by the storms. A spatial and temporal analysis of this rainfall data may provide more information on the rainfall patterns of hurricanes.

Acknowledgements

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