Transactions of the Illinois State Academy of Science
(2004), Volume 97, #1, pp. 45-54

received 10/22/03
accepted 2/4/04

Unusual Rainstorms in Illinois Produced Unusual Impacts

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ABSTRACT

Two intense, short-duration rainstorms occurred in Illinois and adjacent states during mid-August 2002, and many storm characteristics (duration, orientation, rain intensity, and weather conditions) were similar to those of 36 past Illinois-centered rainstorms assessed in detail over the past 50 years. However, the 2002 storms had two features unlike those found in any prior rainstorms assessed. The two storm events occurred just 2.5 days apart and in adjacent areas, and no past storms had occurred in such close time proximity. Slow movement of the stationary front, the focus of the two storms, caused these two storms to occur within a 72-hour period. The other difference concerned the pre-storm summer moisture conditions. Both August storms occurred where antecedent summer rainfall was much below normal and temperatures above normal for 2.5 months, creating much below normal soil moisture conditions. All 36 prior storms studied occurred where pre-storm rainfall was at or above average, and this difference in moisture greatly affected the impacts produced by the August 2002 storms. Neither storm produced the magnitude of flood damages that comparable prior storms had done. The heavy August 2002 rainstorms recharged the soil moisture leading to major increases in soybean yields, representing a gain of $51 million—the first time flash-flood type storms in Illinois have resulted in financial benefits.

INTRODUCTION

Heavy, short-duration rainstorms that produce flash floods have major effects on hydrologic design and operations. Such events are of particular concern in the Midwest because flood damages are excessive with Iowa's historical flood losses ranking first nationally, Missouri's fourth, and Illinois' losses sixth (Changnon et al., 2001). Hence, such intense rainstorms have been under investigation in Illinois since 1950, to gather data necessary for planning and operations and to understand their impacts (Huff, 1993), and also to obtain definitive information about the synoptic weather conditions that cause such events (Huff, 1978).

Every Illinois-centered storm that produced 10 inches (25.3 cm) or more in 1- to 2-day periods since 1950 has undergone intensive study, involving field surveys to gather the spatial rainfall and damage data essential to defining the dimensions and characteristics of such events. By 1964, ten such storms had occurred and their various characteristics

(size, shape, duration, etc.) were used to develop an initial physical-statistical model of such storms (Huff and Changnon, 1964).

Assessment of subsequent storms yielded a sample of 26 such intense additional rain events by 1979. These underwent an extensive analysis to define shapes, orientations, durations, area-depth relationships, and the frequency of area mean rainfall amounts for 6- to 48-hour periods (Huff, 1979). Such events typically produced rainfall amounts of 5.1 cm or more over 26,500 km^2 , peak rain amounts of 25.5 cm or more, rain that began at 1900CST and lasted 8 to 10 hours, a storm pattern oriented WSW-ENE, and length-to-width ratios of 3.8 to 1. All occurred over areas that had experienced average to above average rainfall in preceding months, and in 65 percent of the storms, the antecedent rainfall in the 10 days before the storms was more than 2.8 cm above average. All the past storms produced extensive flash- flooding, major damages in urban areas, severe crop losses, and soil erosion.

Subsequent Illinois rainstorms including those with the 1993 flood (Kunkel, 1996), in 1996 (Changnon and Kunkel, 1999), and in 2001 (Changnon and Westcott, 2002) were similarly intensively field measured and studied, adding to the wealth of storm information. Characteristics of these ten recent storms all fit the 1979 model of rainstorms (Huff, 1979), suggesting that causes and dimensions of Midwestern intense short-duration rainstorms had been adequately defined. Except for two unusual features, characteristics associated with the August 18-19 and August 21-22, 2002 storms were similar to prior analyzed storms. This paper presents brief descriptions of these two storms and their characteristics, and then focuses on the two anomalous conditions associated with the storms.

DATA

Data that allowed definition of the rainfall patterns came from several sources. This included the first-order stations and cooperative substations operated by the National Weather Service (NWS). Other data came from dense networks of recording raingages operated by the Illinois State Water Survey. One network in central Illinois had rainfall from the August 18-19 storm, and the other in northeastern Illinois had rainfall from the August 21-22 storm. Data also were obtained from the 21 recording raingages in the Illinois Climate Network with sites scattered across Illinois. Data from these networks, plus that from several NWS stations, were hourly amounts. County extension agents in numerous counties assisted by providing data collected from farmers with gages. A field survey was conducted, resulting in more than 260 field point measurements of storm total rainfall. Streamflow data were obtained from the U.S. Geological Survey, soil moisture data from the Illinois Climate Network, and crop yield data from the Illinois Farm Bureau.

STORM RAINFALL

The first storm began at 2100 CST on August 18 in western Illinois. Heavy rainfall developed as the convective raincells moved eastward with the most intense rains beginning at 0200 CST on August 19 in east-central Illinois where the maximum total storm rainfall occurred (Fig. 1). The rain lasted between 6 and 8 hours at most points. The

storm system moved eastward across central Indiana, reaching the Indianapolis area by 0700 CST on the 19th and ending as it reached the Indiana-Ohio border at 1100 CST. The total storm rainfall pattern (Fig. 1) has an elongated west-east elliptical shape typical of past storms and peak amounts of 26 cm. At locations where storm totals equaled or exceeded 7.6 cm, point durations were 5 to 6 hours. These 7.6-cm rainfall values rate as once in 10-year values for 6 hours. The 10.2-cm values (Fig. 1) rate as once in 25-year values; those 11.4 cm or more rate as once in 50-year values; and those of 12.7 cm or more achieve the once in 100-year status. An area of 6,086 km^2 experienced 100-year or greater return values.

The second August rainstorm began 2.5 days later in eastern Iowa at 1900CST on August 21. Heavy rainfall developed when the storm cells reached Dubuque (Fig. 2) at 2000 CST. The storm system, a complex of thunderstorms, moved eastward and the heaviest rains fell between Dubuque and Rockford, with totals exceeding 30.5 cm. By midnight the storm system had reached Chicago's northern suburbs, where amounts exceeded 15 cm, and the storm dissipated over Lake Michigan. Most point rainfall durations ranged from 7 to 10 hours. The total storm rainfall pattern also has the typical west-east elliptical shape (Fig. 2). This storm produced 5.1-cm amounts over 26,300 km^2, and the August 18-19 storm over 24,130 $km^{2,}$, values similar to past storms.

Assessment of the storm rainfall based on durations of 12 hours, which embraced all point durations, reveals areas with 12.7 cm ranked as 25-year events; values of 14 cm or more rate as 50–year values; and those in excess of 16.5 cm are amounts expected to occur at least once in a 100-year period. More than 6,900 km^2 had rains at the 100-year level for 12-hour durations. In all these storm categories, the two August storms matched those of the 36 past storms. Weather conditions causing the two August events were also similar to those of most past rainstorms, with the storms developing just south of an west-east oriented stationary front.

However, two features of the August storms were distinctly different from past storm conditions. First, the August 2002 storms occurred within 2.5 days of each other, being much closer in time than any previous storms. The closest events in the prior 52 years had been a pair of rainstorms during the summer of 1957 that were 12 days apart and caused by totally different weather systems. The weather conditions leading to the past 36 rainstorms had either dissipated after the storm or moved far away. However, the frontal system related to the August 18-19 storm moved only 180 km north over the ensuing two days and it stalled there causing the August 21-22 storm (Hilberg, 2003).

The other difference in the August 2002 storms was related to the antecedent summer rainfall conditions. Weather conditions across Illinois and surrounding states prior to the two August storms were important. The spring of 2002 was cool and extremely wet, rated as fourth wettest in the Midwest since 1896. June was warm with Midwest temperatures 1.5° to 2.5° C above normal. Midwestern precipitation was 1 to 2 cm above normal, but was 1 cm below normal in the Illinois areas where the two storms later occurred. July temperatures were 2.5°C above normal and precipitation was below normal across Illinois and Iowa, being 5 cm below normal where the northern storm occurred and 3.5 cm below normal where the central Illinois storm would occur. The first two weeks of August continued the dry conditions in the two storm areas, being 2.5 cm below normal

in both storm areas. The anomalous dry areas amidst wet areas is a reflection of the randomized nature of variability typical of Midwestern convective rainfall (Changnon and Huff, 1980).

Thus, the two areas where the two storms occurred were localized areas of quite dry conditions for 2.5 months before the storms, whereas precipitation in other surrounding areas was near normal. The above normal temperatures and dry pre-storm conditions enhanced evapotranspiration, creating low soil moisture values. This pre-storm dryness was quite different than the average to above average rainfall conditions that existed prior to the 36 analyzed storms since 1950. This difference in pre-storm conditions had a profound effect on the types of impacts caused by the August 2002 storms.

IMPACTS

The most typical impact of such intense rainstorms is flash flooding, and some flooding did occur after both August storms. However, it was limited to areas along stream courses, was very short-lived, and caused only marginal damages.

August 18-19 Storm

Regional precipitation 75 days prior to the rainstorm was only 62 percent of average. This led to dry soils, negatively impacting corn and soybean development during July and early August. Regional soil moisture for the 0 to 101- cm depth on July 16 was 70 percent of average, which fell to 40 percent by August 15. Farmers reported soil moisture was deficient across 91 percent of the area where the storm occurred (Farm Week, 2002). By August 25, the region's soil moisture for the same depth (0-101-cm) was 125 percent of average, and only 11 percent of the region's farmers reported soil moisture as below average. This was a dramatic increase from the pre-storm values.

Flow conditions on river basins in central Illinois where the heavy rains occurred were examined to determine the hydrologic impact of the storm on streamflows. Pre-storm flows were below average for this time of year, and the heavy rains on the night of August 18-19 created peak flows that rated in the middle of the historic distributions of annual peak discharges. Despite the high streamflows the heavy rains created, the number of days before flow levels returned to near average for the season, ranged from only 16 to 22 days, depending on location.

The hydrologic impacts were also compared with those with a recent rainstorm when wetter pre-storm conditions existed. All regional basins experienced a peak annual discharge after a June 1998 rainstorm occurred over the same region with rains of 7.6 and 12.7 cm, much less than that experienced in August 2002. The wetter pre-storm 1998 conditions resulted in flows >71 cms on the Vermilion River, as compared to only 5.7 cms there in August 2002, and post-storm peak flows in 1998 ranked much higher. The time required for flows on area streams to return to near normal in 1998 ranged from 40 to 67 days, two to three times longer than in 2002. No significant rain occurred after the 1998 storm.

The heavy rains of August 18-19 fell primarily over rural areas and a few small towns. Impacts were limited to some minor field and rural road flooding, creating $75,000 in

total damages. Although some of the worst hit areas experienced some damage to crops, most agricultural advisors reported that a large percentage of the rainfall soaked into the ground, rather than ponding, because the pre-storm soils were so dry. The moisture in the soil horizon for soybean roots, 0 (surface) to 101 cm, was 125 percent of average after the storm.

A soybean weather-yield model, SOYGRO, with soil and crop conditions based on those of the storm region, was used to estimate soybean yields with and without the heavy August rains. The outcome indicated that the storm rains led to an additional 5 bushels per acre. The value of 5 bushels per acre at $5.30 per bushel (harvest price) represented about $26.50 added value per acre. The storm region contained 1,430,000 acres of soybeans, and if multiplied by the increased value of $26.50 per acre, the rains produced higher yields worth $37.9 million in Illinois. There was no marked change in corn yields because the rains came too late in the growing season to provide help. July is the critical time for rainfall to affect corn production.

August 21-22 Storm

The dry conditions for 2.5 months before this storm produced soil moisture measured as 65 to 70 percent of average in the 0-to-101 cm soil horizon across northern Illinois. Soil moisture values recovered after the storm and were 110 percent of average when measured on September 1-2. River basins in the storm area were examined to ascertain the hydrologic impact of this storm on streamflow levels. In all basins affected by the heavy rains, the peak discharge occurred either one or two days after the rainstorm ended, with the delay dependent on the basin size. Some basins experienced an increase of flow registered as the annual peak discharge for 2002, but these were not close to being record annual peak discharges. The number of days required to return to an average flow on various regional stream basins ranged from 10 to 24 days, an outcome similar to those for central Illinois river basins affected by the August 18-19 storm. These results reveal that large amounts of the northern Illinois heavy rains infiltrated the dry soils. By August 25 only 9 percent of the region's farmers reported soil moisture as "short" (Farm Week, 2002).

The hydrologic conditions of the affected basins were compared with those associated with another recent heavy rainstorm that occurred in August 1996. Although the rainfall amounts associated with the 1996 storm were less (ranging from 7.6 to 12.7 cm) than those in the 2002 storm, the rain in 1996 storm fell over much wetter ground with above average rain amounts during the 60 days prior to the August 1996 storm. Streamflow conditions prior to the August 1996 storm were more than double the magnitude of those of the August 2002 pre-storm conditions, and on several basins, the peak flows were highly ranked annual events. The August 1996 post-storm flows on area streams took from 30 to 45 days to return to average levels, as compared to 10 to 20 days in August 2002.

Storm-related flooding caused problems in the Chicago suburban area. Two interstate highways in the Chicago region were partially blocked by high water for a few hours. (Chicago Tribune, August 22). The heavy rain caused delays and cancellations of 22 flights at Chicago's O'Hare Airport. Urban-flooding also shut down two of Chicago's commuter rail lines for 8 hours. Some suburban retention ponds overflowed causing

localized flooding. The Chicago Deep Tunnel storage system was filled and more than one billion gallons of untreated storm water and wastewater were released into Lake Michigan, forcing the closure of beaches. Several rural roads across northern Illinois were damaged, requiring repairs. However, the direct impacts of the record rains were less than expected based on prior storm studies (Changnon and Westcott, 2002). The storms also led to power outages in Rockford. Total damages from this Illinois storm were estimated at $260,000. A similar rainstorm in the same area during July 1996 caused $0.65 billion in damages (Changnon, 1999).

Most regional farmers indicated they welcomed the rainfall associated with the August 21-22 storm, especially in terms of their soybean crops. The rains were too late to help the corn crop, after a dry summer, but numerous farmers interviewed expressed a belief that the rains helped the soybean crop by adding more pods and increasing yields. The SOYGRO weather-yield model, with soil and other conditions representative of the storm region, was used to estimate soybean yields with and without the heavy rains, and results indicated that this late season heavy rainfall improved yields about 1.2 bushels per acre. The Illinois and Iowa area with moderate to heavy rains on August 21-22 contained 2,565,000 acres of soybeans, and if a bushel per acre was added to each acre at fall prices of $5.30 per bushel, the added value of the rains was about $13.6 million. The considerable magnitude of the rainstorms of August 2002, and the low magnitude of their economic losses, in contrast to those of other similar earlier rainstorms, is considered to be a result of the exceptionally dry pre-storm conditions in the storm areas.

SUMMARY

The two August 2002 rainstorms, centered in Illinois and extending into adjacent states, created record-setting point rainfalls of >25.5 cm. Return intervals of both storms' heavy rain amounts for 6- and 12- hour durations exceeded values expected to occur once in 100 years.

In many respects the characteristics of the two storms were similar to those of 36 past Illinois-centered rainstorms during 1951-2001 that had been investigated in comparable detail. The similarities included the fact that 1) all the rain fell in 24 hours or less, with most in 8 hours or less; 2) the heaviest rains occurred during the night; 3) the major axis of the storm areas was oriented west-east; and 4) the areal extent of the region with >5.1 cm covered more than 23,400 km^2. Weather conditions causing the storms were similar to those of many past rainstorms.

However, the two August 2002 rainstorms had two features that were quite different from those in any past Illinois rainstorm assessed since 1951. First, the two storm events occurred just 2.5 days apart and in adjacent areas. No other major past storms had occurred in such close time or space proximity. The closest incidence of any past storms was 12 days, an interval which separated two summer 1957 storms. The minor movement of the stationary front that served as the focus of the two August 2002 storms caused these two storms to occur in a 3-day period.

A second major difference concerned the pre-storm precipitation and soil moisture conditions. Both August storms occurred in areas where the rainfall for 2.5 months before the

storm had been below normal and temperatures much above normal, creating much below normal soil moisture and drought-like conditions for crops. In contrast, all prior 36 major rainstorms occurred after 2-month or longer periods of average to much above average rainfall. The low pre-storm rainfall in the two storms areas was a result of the random natural variability of convective rainfall with above normal rainfall in the areas adjacent to the storm areas.

Regardless, the pre-storm difference in moisture conditions greatly affected the kinds of impacts produced by the two August 2002 storms. Neither storm produced the magnitude of property and crop damages that comparable prior storms had done. Damages and losses from the August 21-22 storm were estimated at $260,000, mainly a result of problems in Chicago, and damages from the August 18-19 storm were only $75,000.

The August 2002 soils were very dry and thus a much greater percentage of the total storm rainfall infiltrated the soil, resulting in less runoff. The flows of the rivers in basins where the heaviest rains fell achieved high early peak flows sufficient to rank as annual peaks for 2002, but their flows quickly dropped and returned to average seasonal levels within 10 to 22 days after the storms. This time of return to normal levels is two to three times faster than found in prior storms with wetter pre-storm conditions. Some flood-related losses occurred immediately after the August storms, but the flooding quickly dissipated and was largely concentrated in lands adjacent to rivers and major streams near the core of the storms.

Flood-related losses were minimal, and the unusual major economic impact of the two August storms related to the enhanced soil moisture. This led to positive effects on the maturing soybean crops. Spring weather conditions had delayed soybean planting and the crop was in its pod-filling stage and with low soil moisture when the storms occurred. The heavy rains saturated the root zone soils, leading to increases in soybean yields. The added yields were worth an estimated $13.6 million in northern Illinois-Iowa and $37.9 million in east-central Illinois, a total in excess of $51 million. Thus, the two 2002 rainstorms have put a new dimension on the characteristics of Illinois rainstorms.

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Figure 1. The total storm rainfall, in centimeters, for August 18-19, 2002 storm.

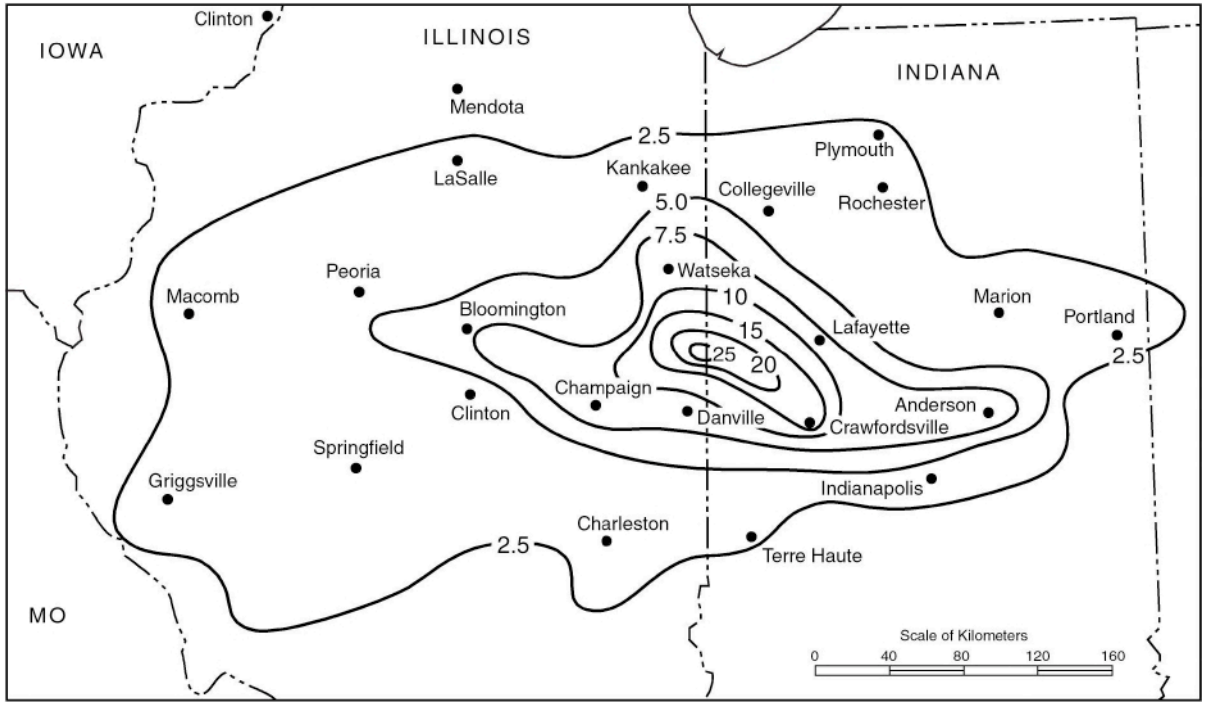

Figure 2. The total storm rainfall, in centimeters, for August 21-22, 2002 storm.