Analysis of the July 12-13, 2021, Flash Flood near Seneca, IL

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National Weather Service Chicago, IL
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Summary

Very heavy rainfall from a nearly-stationary thunderstorm occurred in the vicinity of Seneca, Illinois, the evening of July 12, 2021, causing flash flooding in portions of La Salle and Grundy Counties through July 13. The thunderstorm impacted the area from about 6:30 PM (2330 UTC July 12) through about 10:30 PM (0330 UTC July 13), moving very little over that time (Figure 1).

Gridded rainfall estimates indicated that an isolated portion of La Salle and Grundy Counties received heavy rainfall, with the heaviest rainfall near the La Salle/Grundy County boundary just south of Seneca. Data from 14 rain gauges was collected and analyzed with the gridded rainfall estimates. Rainfall was also compared to the NOAA Atlas 14 to place rainfall amounts into climatological context. The highest analyzed storm total rainfall was approximately 7.0-7.5 inches which occurred over a 4-hr period ending at 10:30 PM July 12 (0330 UTC July 13). Of that total, approximately 6.5-7.0 inches occurred in the heaviest 3-hr period and approximately 4.5 inches occurred in the heaviest 1-hr period. Observed rainfall ranged from typical to extreme over La Salle and Grundy Counties with a very sharp gradient toward values of increasing severity. Maximum rainfall amounts had less than a 1% chance of occurring annually.

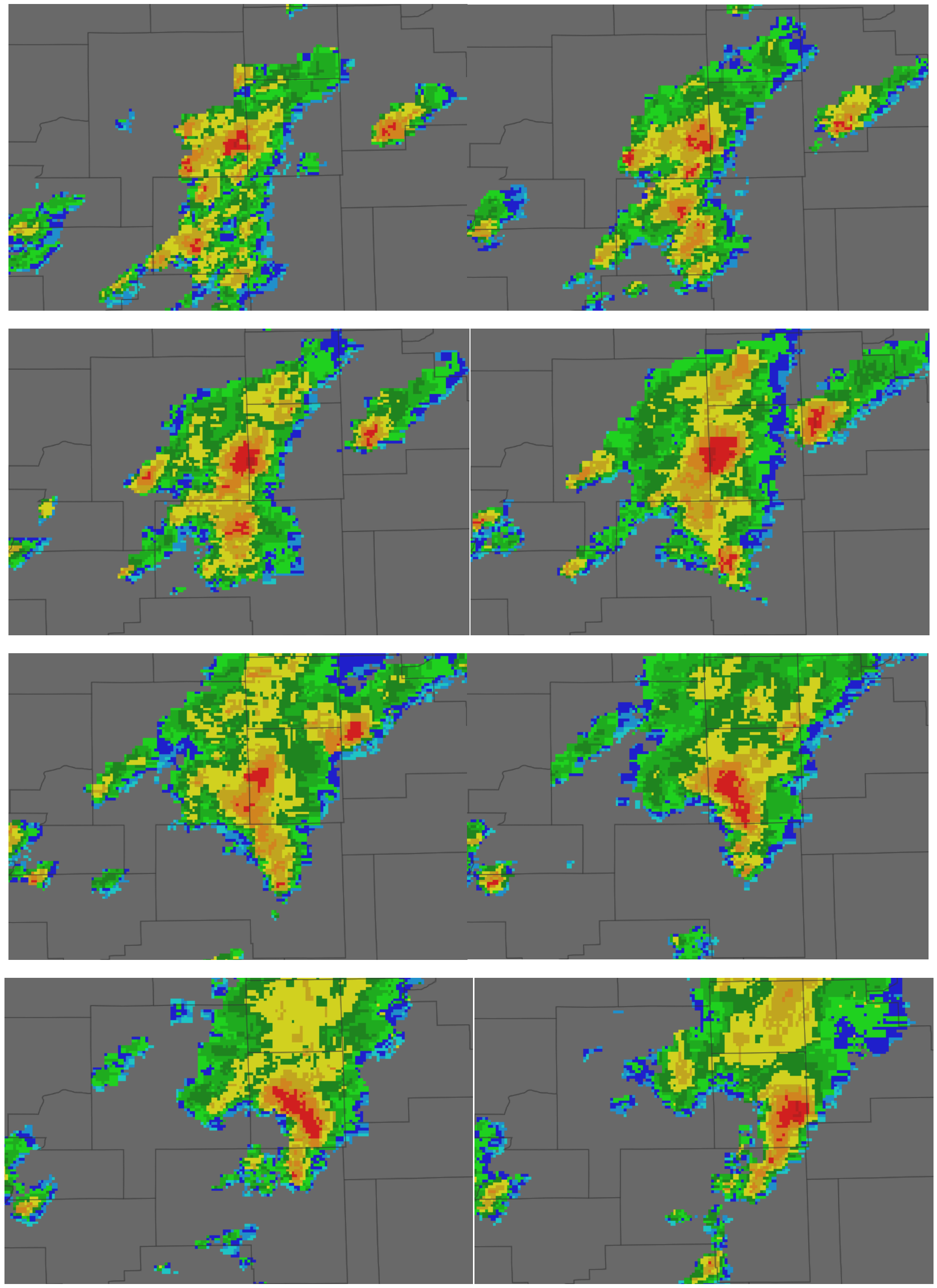

Figure 1. Radar imagery of the thunderstorm which caused flash flooding July 12-13, 2021, in La Salle and Grundy Counties, Illinois. Images are approximately 30 minutes apart, in left-to-right, top-to-bottom order, beginning at 7:30 PM and ending at 11:00 PM.

Meteorology

An upper-level, closed area of low pressure was moving slowly across northern Illinois the evening of July 12, 2021. Closer to the surface, a weak area of low pressure was evident. At 7:00 PM July 12 (0000 UTC July 13), temperatures were generally in the low-to-mid 70s with dewpoints in the upper 60s to near 70. There was a slight gradient in temperatures and dewpoints, increasing from northwest to southeast. Precipitable water values were above average, near the 90th percentile value for that time of year. Wind speeds above the surface were generally light except for near the jet stream at the top of the troposphere. Some moisture convergence was evident just to the east of the area of low pressure. These factors supported the development of heavy rainfall and slow storm movement which can lead to significant rainfall accumulations in isolated locations.

Some available forecast information indicated that rainfall could occur due to this area of low pressure. The HREF valid at 1200 UTC July 12, for example indicated a 30-50% chance of 3-hour rainfall exceeding 1 inch and about a 10% chance of a 3-hour rainfall exceeding 3 inches.

Data Sources and Data Collection

The official rainfall estimates created by the National Weather Service (NWS) come from the River Forecast Centers (RFCs). Gridded rainfall estimates come from radar estimates adjusted (bias-corrected) to better match observed rainfall at rain gauge locations. Gridded rainfall data is then manually quality controlled each hour. Data becomes available 30-60 minutes after the top of the hour, but may still be reviewed and adjusted by NWS forecasters for a few days after the rainfall occurred due to the availability of additional data. It should be noted that during real-time operations, local NWS Weather Forecast Offices (WFOs) have access to the unadjusted rainfall estimates from radar which are available every few minutes.

The thunderstorm which produced the heavy rainfall occurred from about 6:30 PM (2330 UTC July 12) through about 10:30 PM (0330 UTC July 13). The storm was nearly stationary during that time period, but then moved eastward toward southeast Grundy County after 10:30 PM. Some light rainfall occurred outside of the indicated time period which caused the "storm total" amounts to be slightly less than the accumulated total over the meteorological observation day ending at 7:00 AM (1200 UTC) July 13 (Figure 2).

A substantial amount of additional rainfall information was collected to perform analysis on rainfall that occurred on July 13. For the areas hardest-hit by rainfall no rain gauges would be available to NWS forecasters in real-time operations. Real-time gauges include those operated by the FAA (ASOS and AWOS) and the US Geological Survey (USGS). Once per day, additional rainfall information is available from manual observations which can be used to further improve gridded rainfall estimates. This rainfall data comes from the NWS cooperative observer program (COOP) and the Community Collaborative Rain Hail and Snow (CoCoRaHS) network and cover a meteorological observation day (24-hour period ending at 1200 UTC or 7AM CDT). Data was available from six (6) of these stations across the area, of which one (1) CoCoRaHS location was in Seneca. There are also numerous additional private weather stations located throughout the larger area of interest that have varying quality and usefulness. Private weather station data is available from the Citizen Weather Observing Program (CWOP) and also from Weather Underground Private Weather Station (WUPWS) network. Data was collected from eight (8) such private weather stations including five (5) in the vicinity of heaviest rainfall. In total, hourly and daily rainfall data was collected for 14 locations (Figure 3).

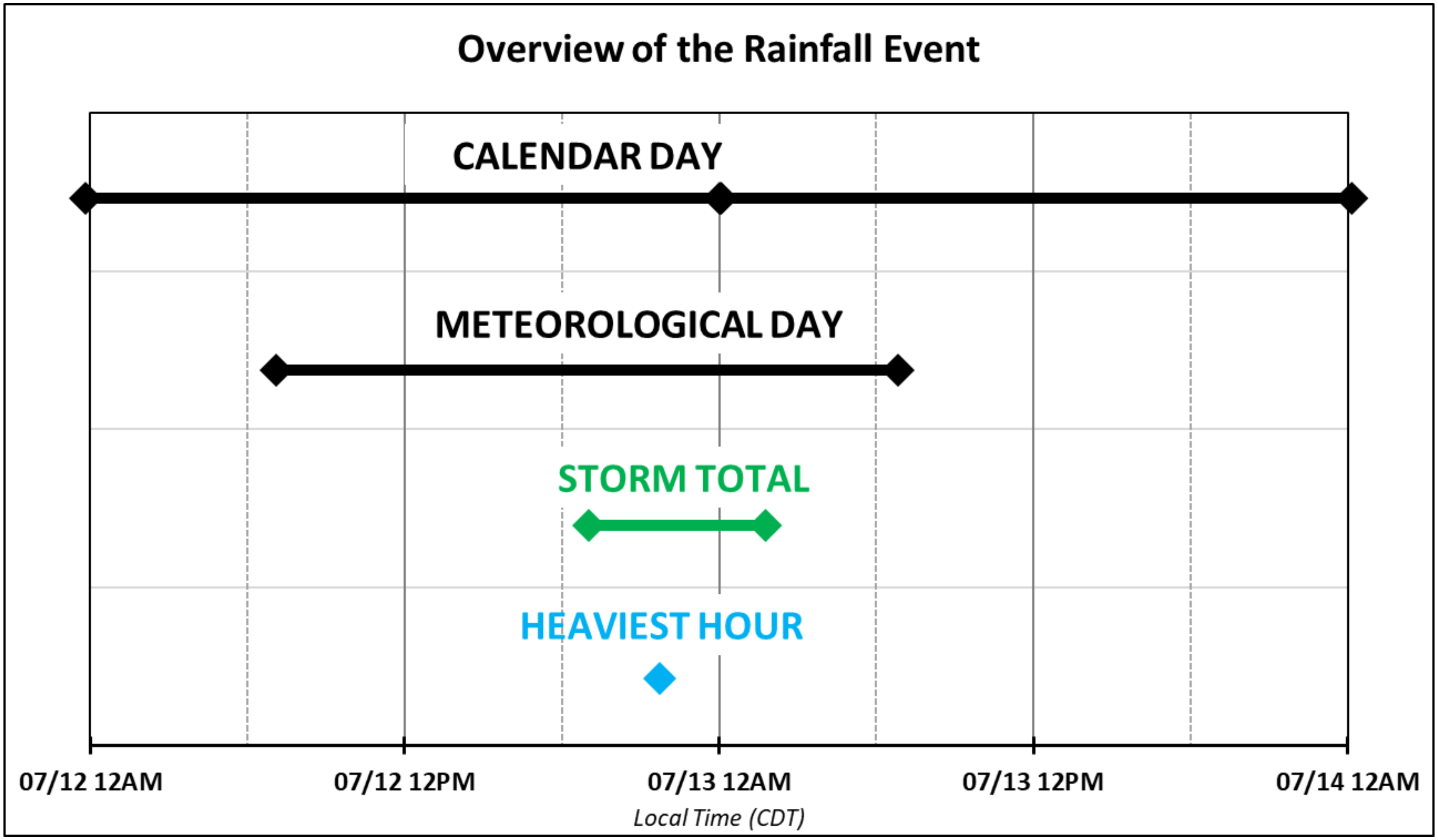

Figure 2. The rainfall making up the "storm total" analyzed for this report spans two calendar days and one meteorological observation day.

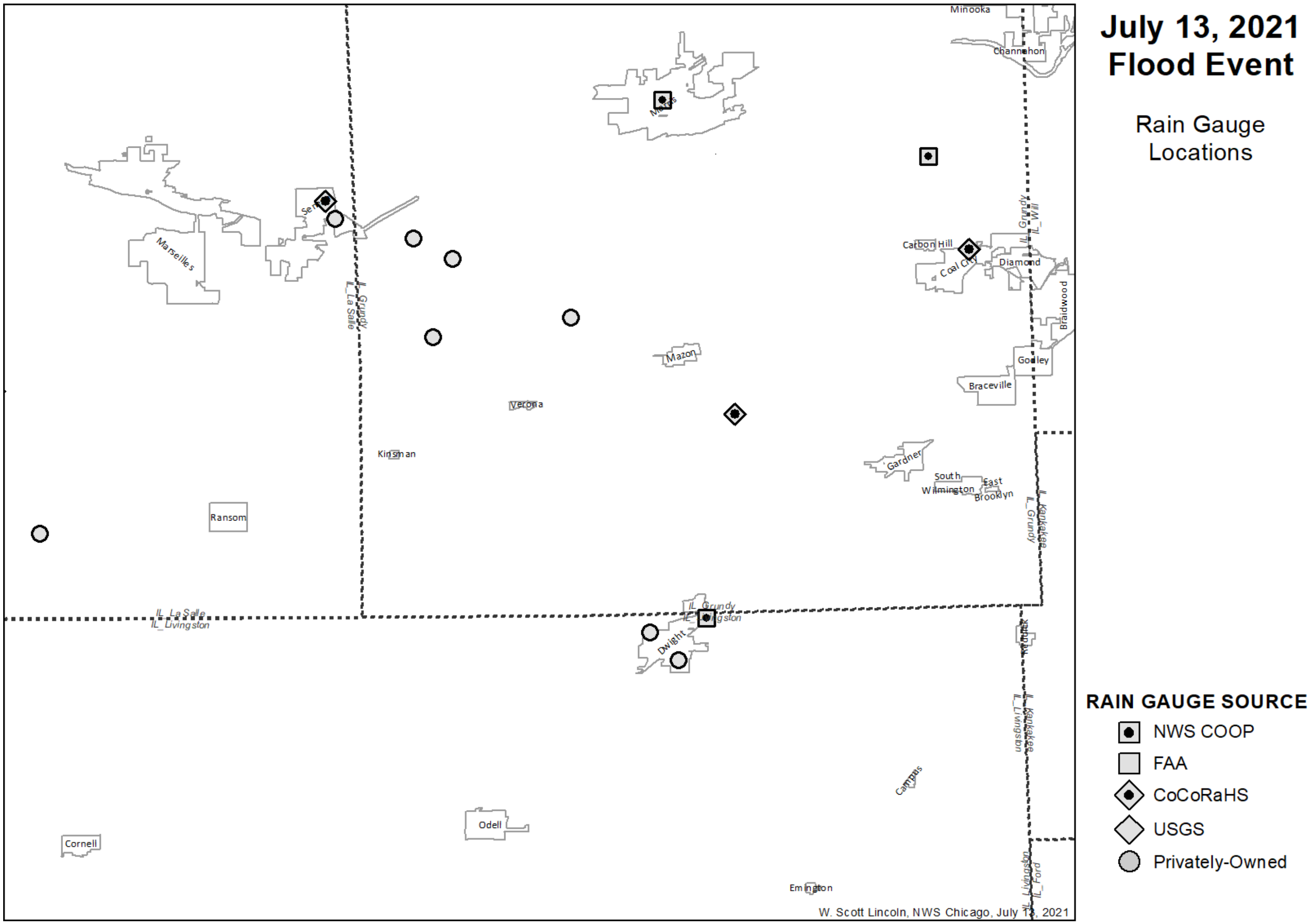

Figure 3. Locations of rain gauge data collected for this analysis. Rain gauges are organized by the source network (COOP, FAA, CoCoRaHS, USGS, or private) and also whether they are daily, manual observations only (black dot).

Rainfall Amounts

Portions of La Salle and Grundy Counties in Illinois received several inches of rainfall between 6:30 PM and 10:30 PM July 12 (2330 UTC July 12 to 0330 UTC July 13). According to the bias-corrected gridded rainfall from the NWS RFCs, most of southeast La Salle County and the southern half of Grundy County received greater than 1.0 inch of rainfall over the 1-day period ending at 1200UTC (7AM) July 13. The heaviest rainfall amounts were estimated to have occurred about three (3) miles south southeast of Seneca, near the La Salle and Grundy County boundary, where 7.0-7.5 inches of rainfall was estimated. A steep gradient from lighter rainfall amounts to higher rainfall amounts was evident. Although small amounts of rainfall occurred at other times within the 1-day period, the overwhelming majority of the rainfall appeared to occur over the 4-hr "storm total" period, and about half of the storm total occurred in just one hour. Rainfall observations collected from the various rain gauge networks was found to be in general agreement with the gridded rainfall estimates (Figure 4). A few gauge observations were slightly lower than gridded estimates while a few gauges close to the rainfall maximum were slightly higher than the gridded estimates. In general, however, the gridded rainfall product was a reasonable depiction of the rainfall that occurred, especially the timing and maximum value. One private weather station just three (3) miles east of the radar-estimated rainfall maximum recorded 6.68 inches of rainfall over the 1-day period while the gridded rainfall estimate indicated 5.1 inches, however this occurred near a sharp gradient. About 1-2 miles west of this rain gauge observation was an area with gridded rainfall estimates ranging from 6.0-7.0 inches. It is possible that the gridded estimates were biased slightly too low and were offset slightly to the west. Performing a bias correction to the gridded rainfall estimates moves the rainfall maximum slightly and increases values slightly (Figure 5).

Based upon all of the available information, it appears likely that a small area near the La Salle/Grundy County boundary south of Seneca received 7.0-7.5 inches of rainfall between 6:30 PM (2330 UTC July 12) through about 10:30 PM (0330 UTC July 13). The most intense rainfall occurred from approximately 9:00 PM to 10:00 PM (0200-0300 UTC) when the hardest hit area accumulated 3.0-4.5 inches. The heaviest rainfall impacted the Spring Brook, Deadly Run, Armstrong Run, Hog Run, Bills Run, and Waupecan Creek Basins (Figure 6). The most significant damage occurred along Spring Brook, Deadly Run, Armstrong Run, Hog Run, and an unnamed creek just west of Deadly Run. A summary of flash flood impacts will be discussed in a later section.

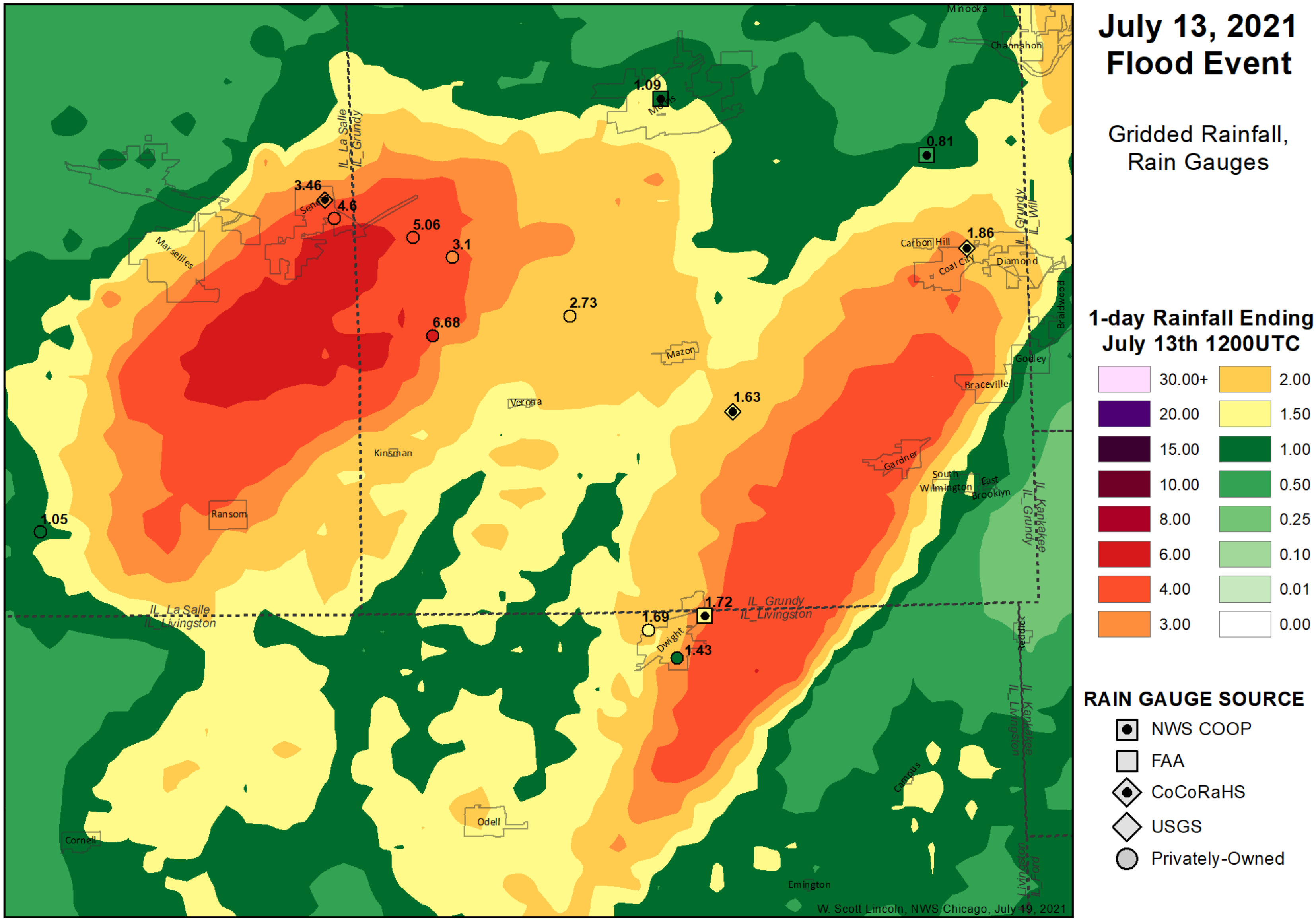

Figure 4. Gridded rainfall estimate covering the 1-day period ending July 13, 2021, at 1200UTC with gauge observations as an overlay. Rain gauges symbolized by source network.

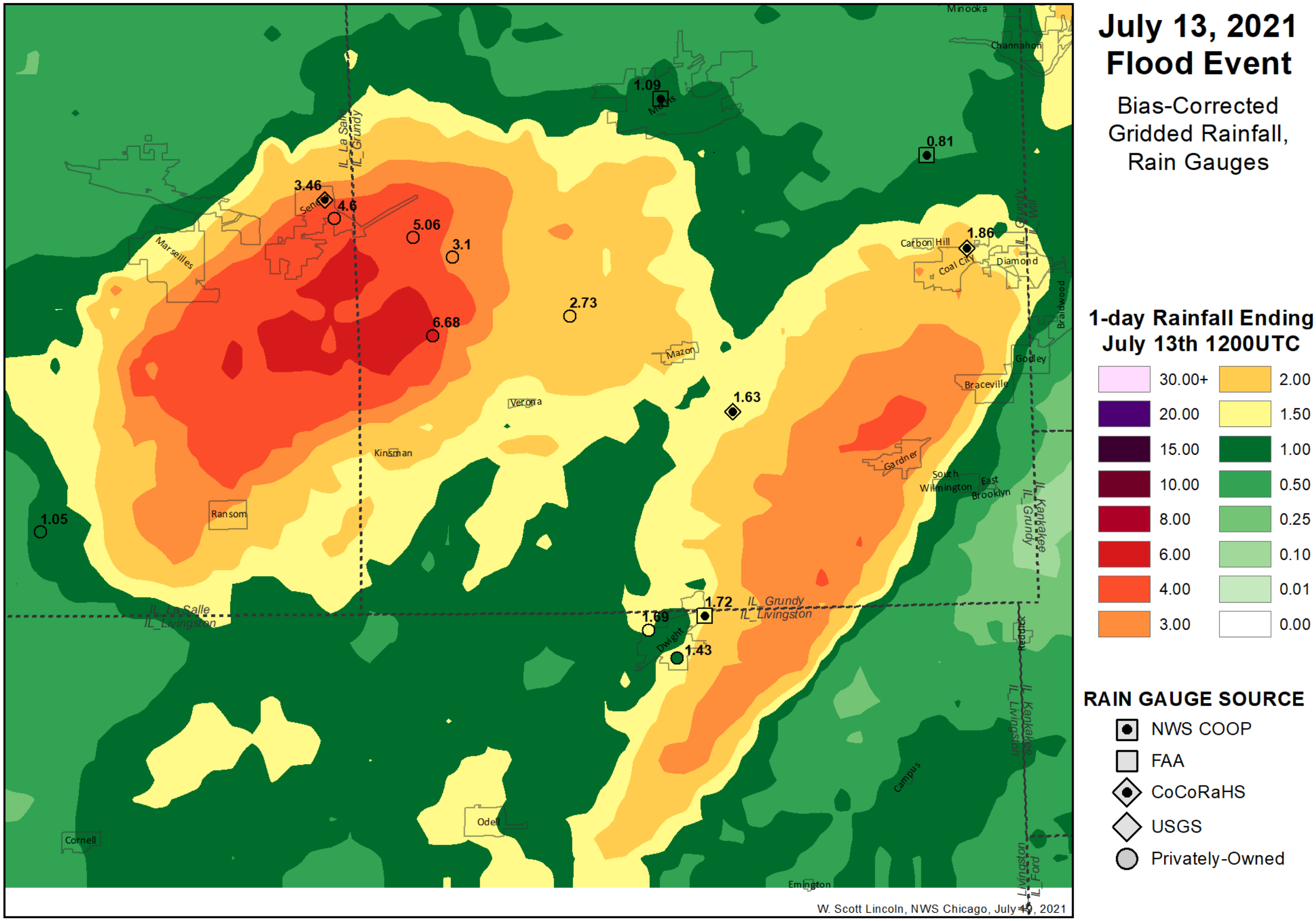

Figure 5. Gridded rainfall estimate covering the 1-day period ending July 13, 2021, at 1200UTC with gauge observations as an overlay. Gridded rainfall was bias corrected to better match gauge observations. Rain gauges symbolized by source network.

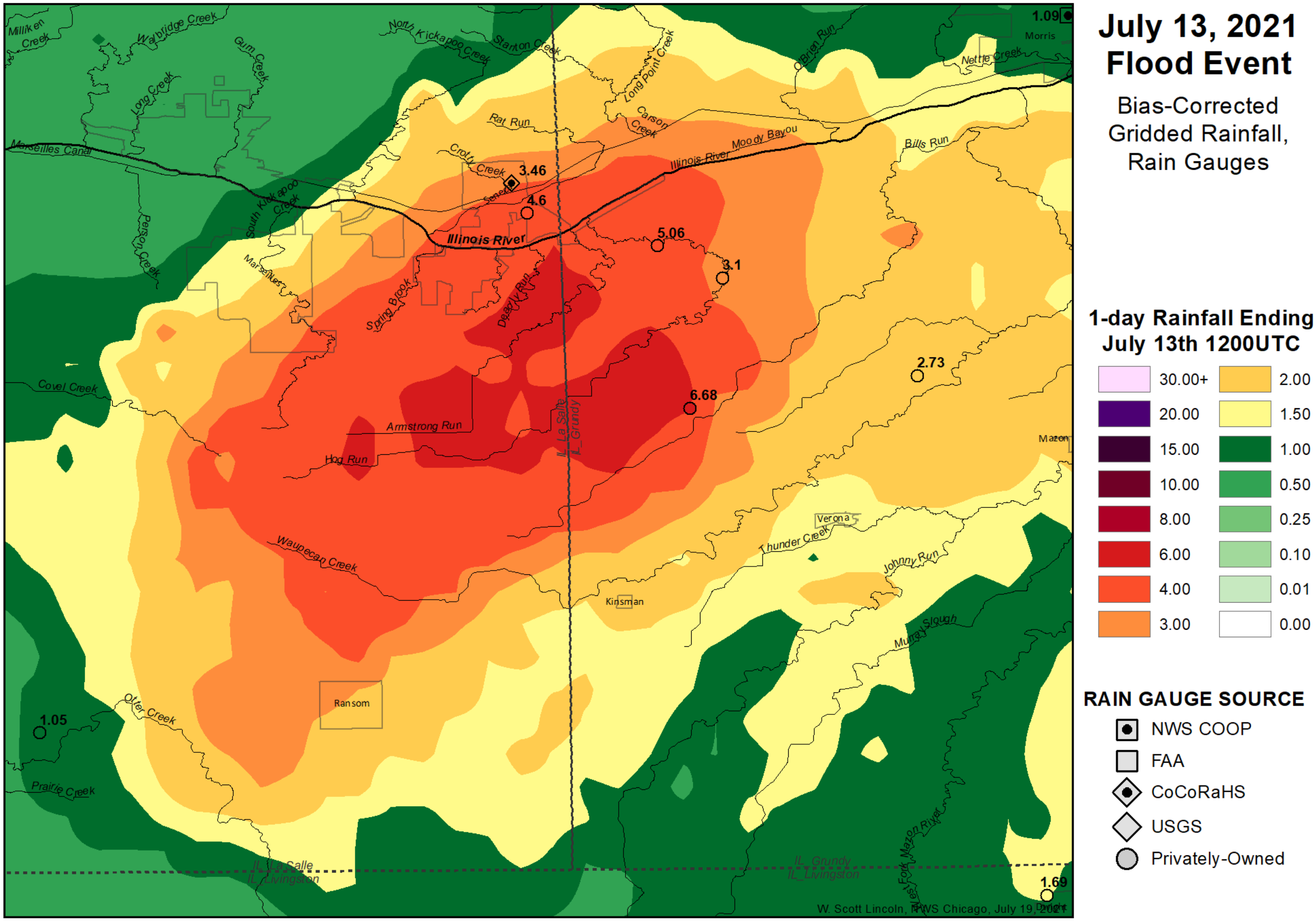

Figure 6. Gridded rainfall estimate covering the 1-day period ending July 13, 2021, at 1200UTC with gauge observations as an overlay. Gridded rainfall was bias corrected to better match gauge observations. Rain gauges symbolized by source network. Rivers and streams added as an overlay.

Climatological Context of Rainfall Amounts

The gridded rainfall estimates were compared to NOAA Atlas 14 which provides estimates of how rare a given amount of rainfall is. The storm total rainfall spanned two calendar days and one meteorological observation day, but the overwhelming majority of rainfall in all locations occurred within a 3-hour to 4-hour period. The storm total rainfall was to rainfall statistics for a 3-hour rain event. From NOAA Atlas 14, the annual exceedance probability (AEP), was calculated for a given rain amount. AEP is related to the more widely (and often inaccurately) used term “average recurrence interval” (ARI). For example, a so-called “100-year event” has about a 1% chance of occurring in a given year (AEP).

Observed storm total rainfall ranged from typical to extreme. Portions of La Salle and Grundy Counties received rainfall with less than a 50% chance of occurring in a given year (Figure 7). Rainfall amounts rapidly became rarer closer to the rainfall maximum near the county boundary. Extreme rainfall amounts (<1% AEP) were recorded in far southern Seneca, extending south southwest and south southeast about 4 miles. About 3 miles south southeast of Seneca, near the county boundary, an isolated area experienced rainfall with a 0.2% AEP. Rainfall of this magnitude is usually associated with significant flood impacts.

Due to the extreme rainfall observed, rain gauges near Seneca were analyzed more closely. The rain gauges with the highest 1-day totals (ending July 13 at 1200UTC) included WUPWS site KILVERON5 with 6.68 inches and WUPWS site KILMORRI52 with 5.06 inches. Hourly data from KILVERON5 and KILMORRI52 confirmed that the overwhelming majority of the 1-day rainfall total occurred within an approximately 4-hour long period including a particularly heavy 1-hr period. Rainfall was extreme (exceeding the 1% AEP) for the 2-hr, 3-hr, and 4-hr durations (Figure 8). Although rainfall was generally ending after four (4) hours, the accumulated rainfall trace for KILVERON5 remained above the 1% AEP value for at least 15 hours. This means that the accumulated rainfall amount would have been extreme even if it had occurred over that longer period, but it instead occurred over just a few hours leading to more significant flash flooding.

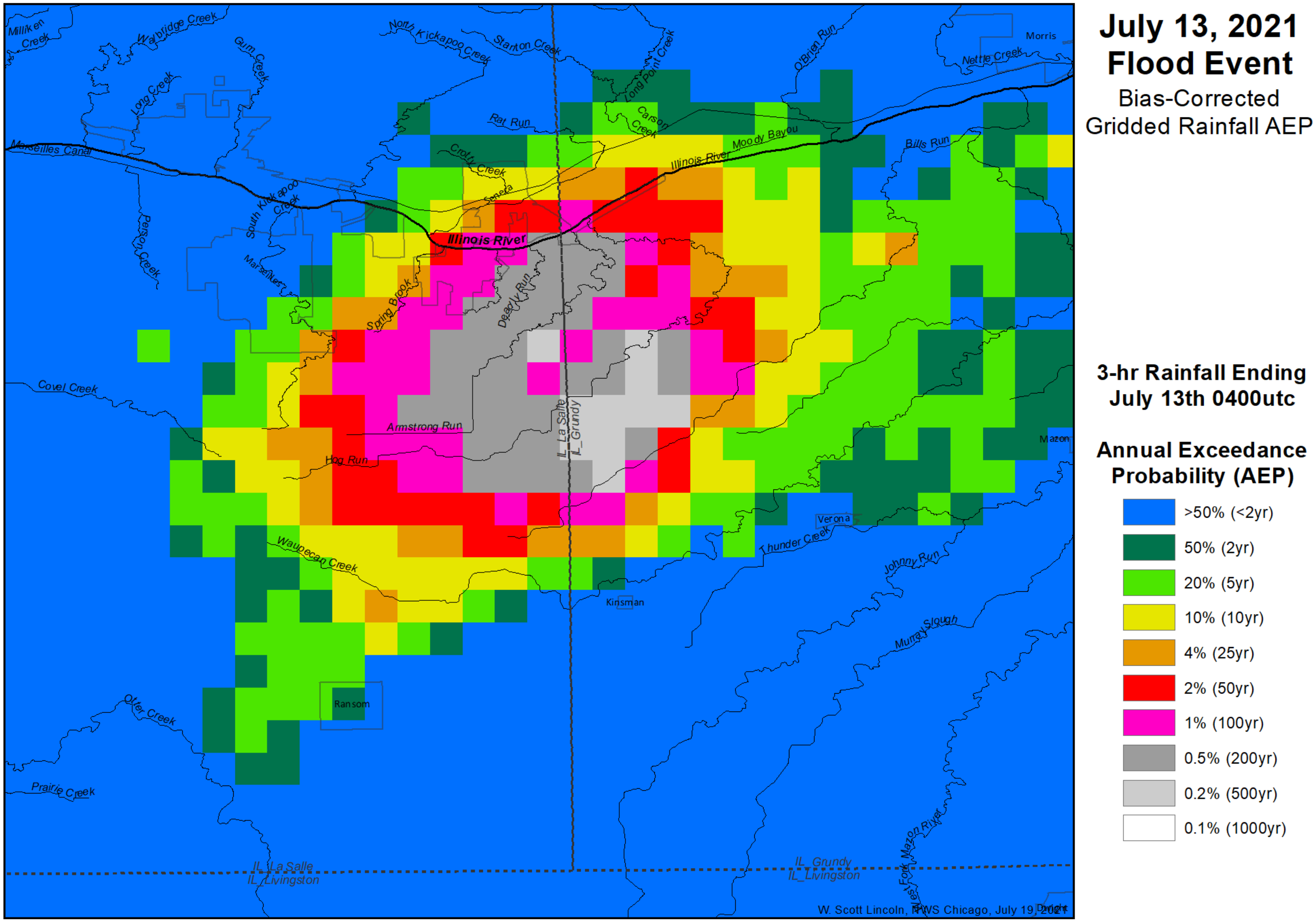

Figure 7. Annual Exceedance Probability (AEP) of the gridded rainfall estimate covering the 3-hr period ending July 12, 2021, at 11:00 PM (July 13 0400 UTC).

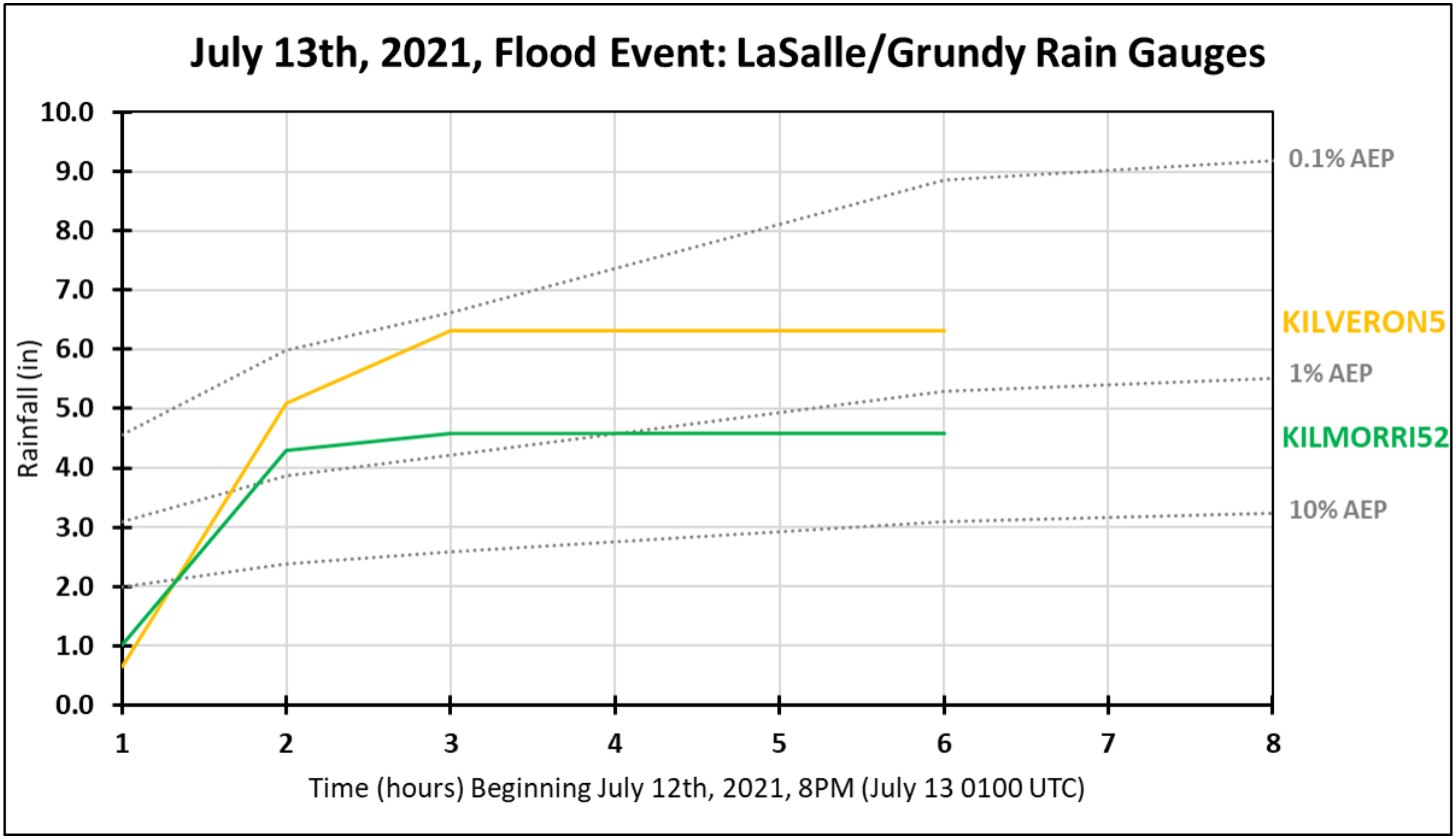

Figure 8. Total accumulated rainfall for two WUPWS sites in the Seneca area beginning at 8PM July 12 (0100UTC July 13). NOAA Atlas 14 data added as an overlay.

Flash Flood Impacts

Rainfall of the magnitude that occurred July 12, 2021, in portions of La Salle and Grundy Counties is usually associated with significant flash flood impacts. Preliminary reports received by the National Weather Service indicated that multiple roadways were flooded and at least one (1) structure was impacted, possibly by surface flow. A survey was conducted on July 16th, 2021, to look for evidence of flash flooding in the impacted area. The survey of impacted areas confirmed significant impacts in a localized area. Evidence was found for the flooding of 5-10 structures due to overland flow, damage to at least four (4) bridges, and 10-20 flooded roadway crossings. The location of surveyed flood impacts is shown by Figure 9.

Based upon the small footprint of heavy rainfall and the short distances between rainfall and impacts, lag time between heaviest rainfall and highest water levels was likely short. Flood wave velocities were estimated at multiple locations within the impacted area using Manning's flow velocity equations and an approximation of flood wave propagation (celerity) being 1.5x the Manning's velocity. Estimated flood wave velocities ranged from 2.5 to 6.0 miles per hour across the area (Figure 10). There is some uncertainty with these estimates likely related to the channel dimensions which had to be approximated from remote-sensed data (LiDAR elevation data). From this information it was estimated that the peak water level in significantly impacted locations likely occurred within 1-2 hours of the peak rainfall.

One resident told the NWS during the survey that water first started flowing over the roadway near their residence east of Spring Brook about 8:47 PM (0147 UTC July 13). The water level continued to climb until water was surrounding the structure and then damaged a window well, flooding the basement. The gauge with the highest rainfall observation just southeast of Seneca did not report the most significant rainfall until the 9-10 PM period, up to an hour later. This discrepancy can likely be explained by the slow movement of the thunderstorm from west to east; areas to the west of the rain gauge were impacted first before the storm drifted over the gauge. Closer to Seneca, the east abutment to the River Road bridge over an unnamed creek washed out at approximately 10:50 PM (0350 UTC July 13) based upon an emergency call received at about 10:55 PM. Media reports indicated that the washout occurred right as a truck carrying a local highway department staff member was driving across. Based upon the estimate of travel time for the stream crest in this area, the washout likely occurred near, or just after, the peak water level. Other impacts along Armstrong Run, Deadly Run, and Hog Run included damage to bridges, flooded roadways, downed trees, erosion of stream banks, and flattened vegetation. Media reports suggest multiple cars were stalled with occupants requiring rescue. No information was available from the survey to narrow down the time for these other impacts, but they also likely began at approximately the time of peak rainfall rates. Hydrologic modeling of the impacted stream basins could be used to approximate the time of impacts in these areas.

At the time of this report, limited information was available about the costs associated with the flash flood event. The mayor of Seneca mentioned during the survey that the River Road washout repair was expected to cost $750,000. The structures on nearby Timmons Lane that were likely flooded with a few inches to a few feet of water could have repairs totaling thousands to 10s of thousands each, according to multiple approximate flood damage calculators. This does not include damage to additional roadways and bridges where no information has yet been received. It is possible that the costs from this event could exceed $1 million.

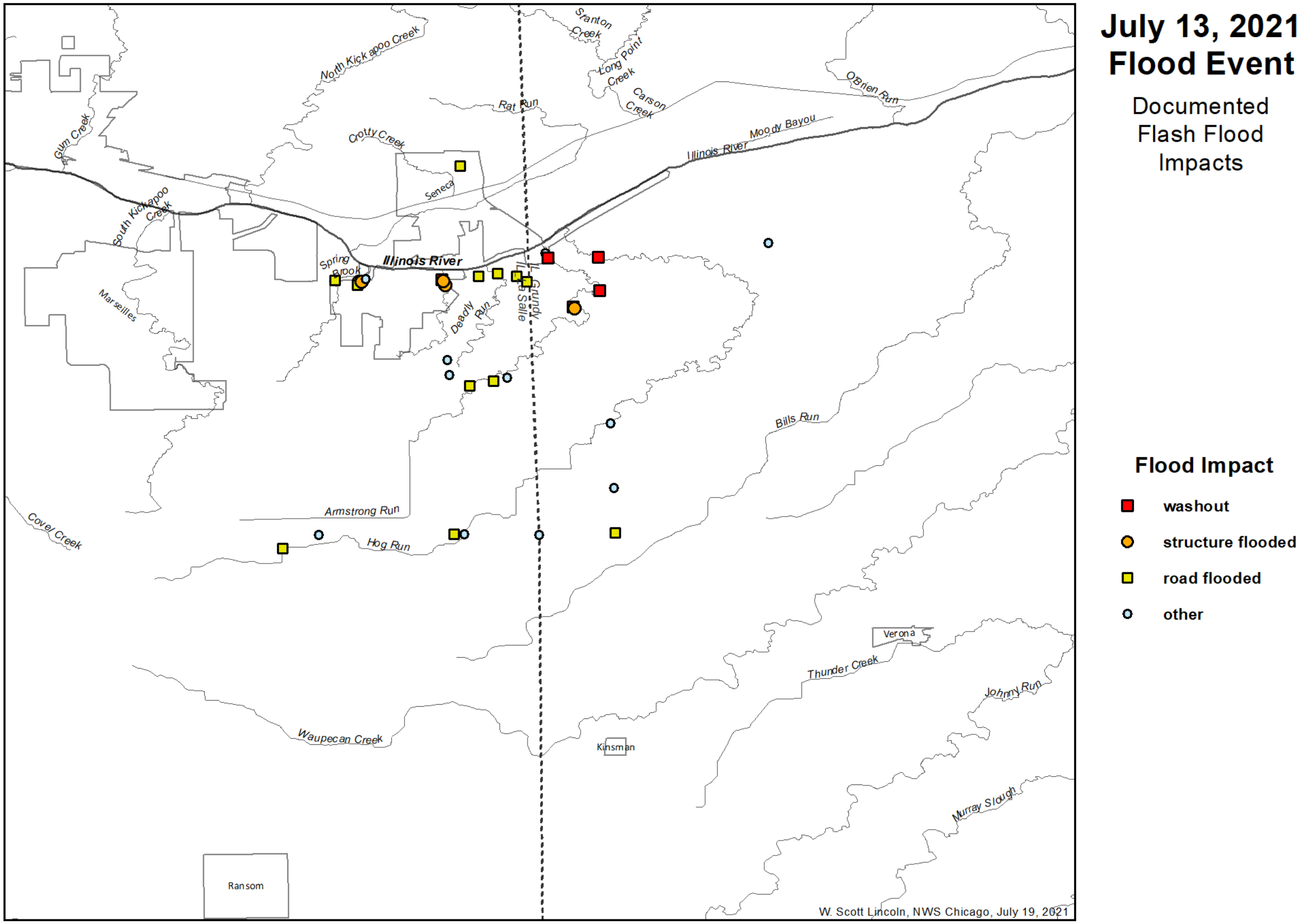

Figure 9. Documented impacts from the flash flood which occurred on July 12, 2021. Reports came from a National Weather Service survey and also some reports from local law enforcement and media sources.

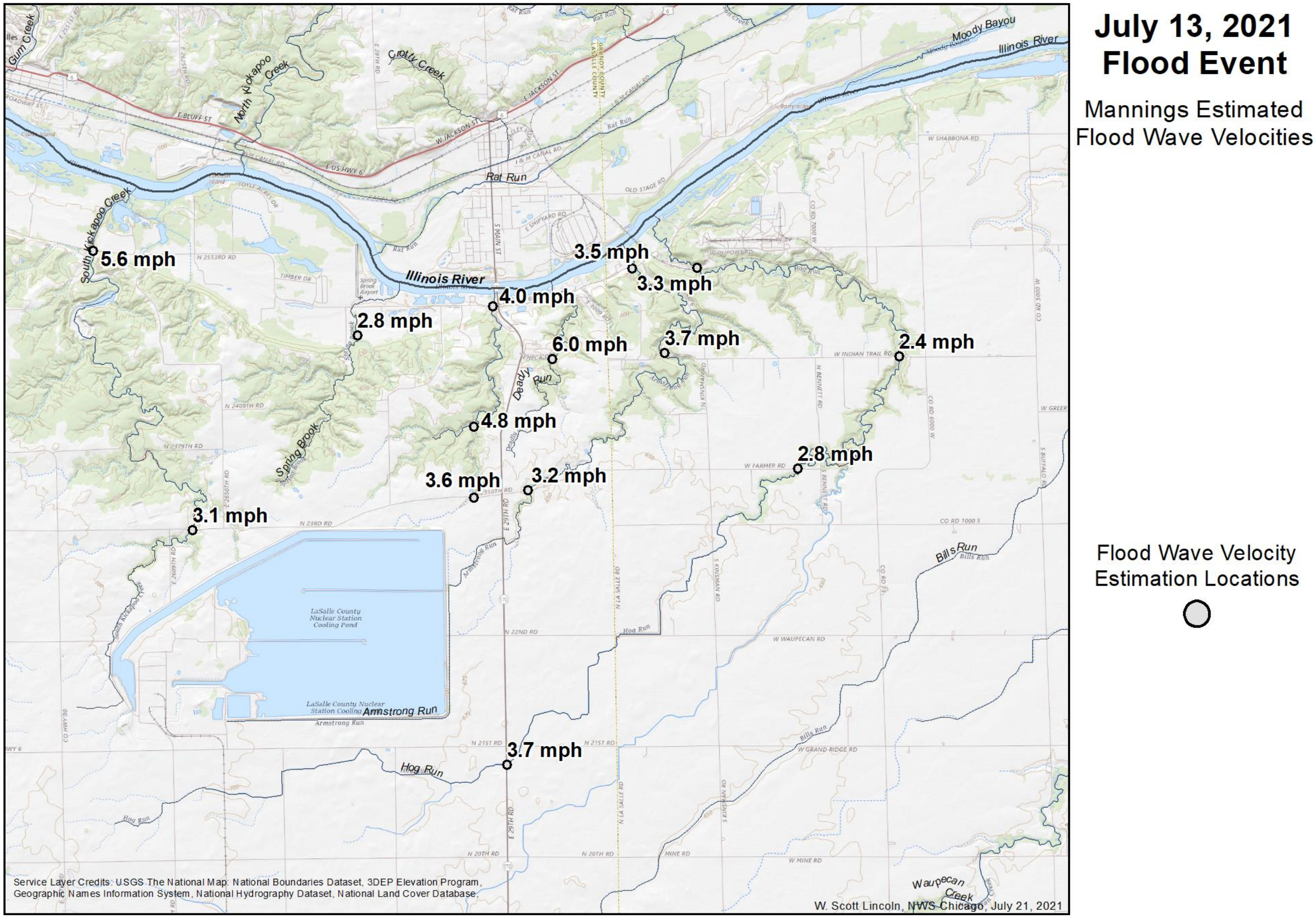

Figure 10. Estimations of flood wave propagation velocities estimated from Manning's flow velocity equation with an adjustment factor.

Hydrologic Modeling

A hydrologic model was developed to simulate the rainfall runoff processes that occurred during the event for the Spring Brook, Armstrong Run, Deadly Run, Hog Run, and unnamed creek basins. Rainfall inputs for each model basin were based upon the 10-min rainfall accumulations from the MRMS radar-only estimates, but with magnitudes adjusted such that storm total rainfall matched the rainfall estimates bias-corrected to gauge observations. Canopy cover in the model was simulated as a simple abstraction ranging from 0.05 to 0.40 inches, depending on GIS estimates of tree cover. Land surface abstractions ranged from 0.10-0.15 inches based upon GIS land cover information. Infiltration was simulated with two different models – Curve Number and Green & Ampt – to provide some means assessing model sensitivity and uncertainty. Curve Number values for each basin were derived from GIS analysis of 2011 NLCD land cover and STATSGO soil type. Green & Ampt values for each basin were derived from GIS analysis of STATSGO soil type. Lag time for each basin and routing between basins were estimated based upon GIS analysis of land cover and slope. The modeled output location for each basin was set to be the location where each stream entered the Illinois River Valley, which was near River Road or DuPont Road, south of Seneca.

Estimates of crests on impacted waterways ranged from 9:20 PM July 12 to 12:55 AM July 13 (0220 UTC to 0555 UTC July 13), with the earliest crests generally occurring closer to the rainfall maximum (Figure 11). For most locations, output from both infiltration methods produced similar results, both the magnitude of the streamflow crest and the time of crest (Figure 12). The exception was Spring Brook at River Road, where a significant difference was noted between the peak streamflow. Simulated streamflow crests at the basin outlets generally occurred approximately 1-3 hours after the rainfall center of mass, except for Hog Run which crested about 5 hours afterward due to the longer travel path. Timing differences between the two infiltration methods ranged from 5 to 15 minutes. Based upon some limited anecdotal information about the rising water on some of these waterways, it is possible that the modeled crests occurred slightly after the actual crests. The extent to which a time bias may exist for this model is nearly impossible to determine based upon the available information.

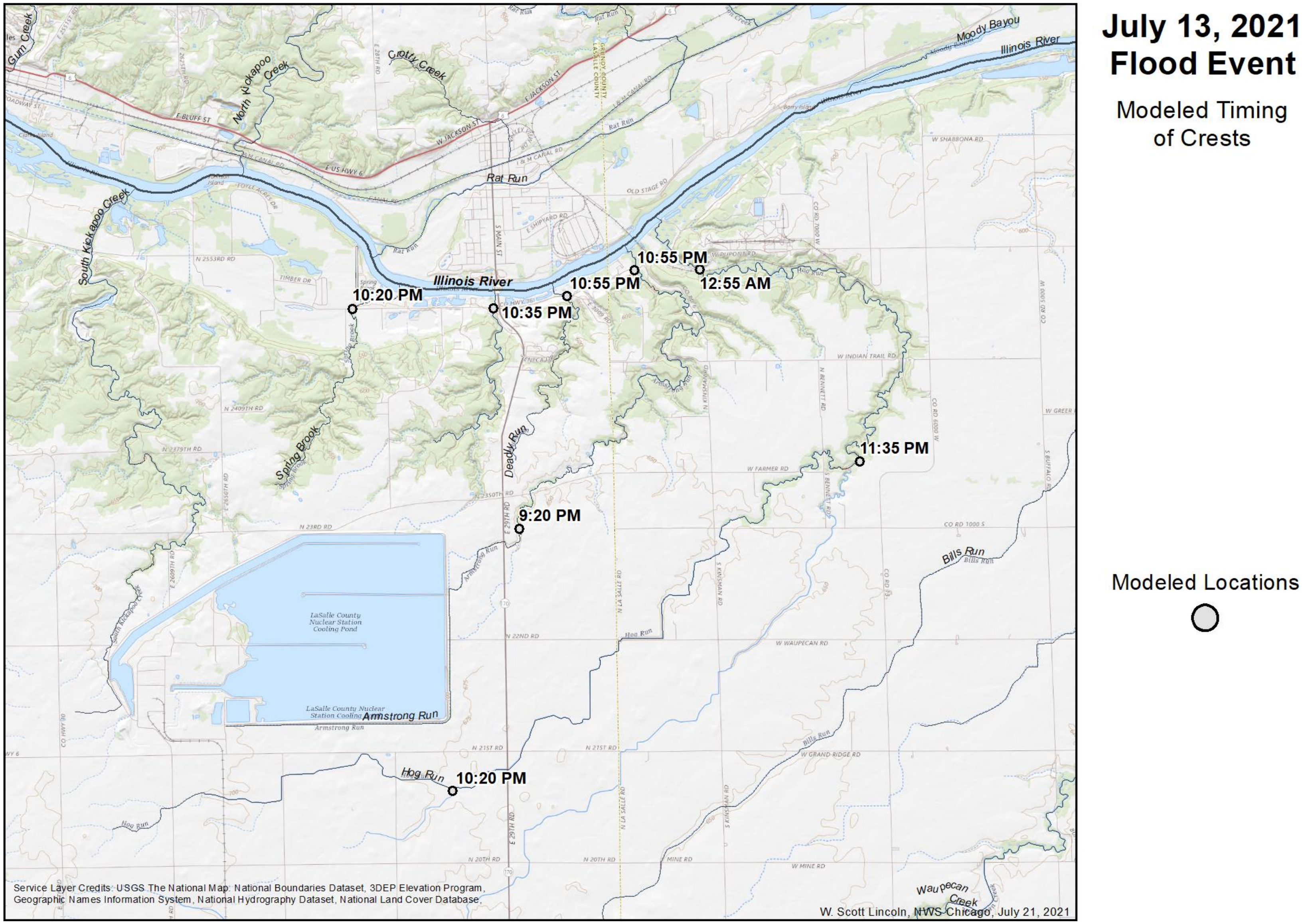

Figure 11. Approximate time of crests (local time CDT) from hydrologic modeling.

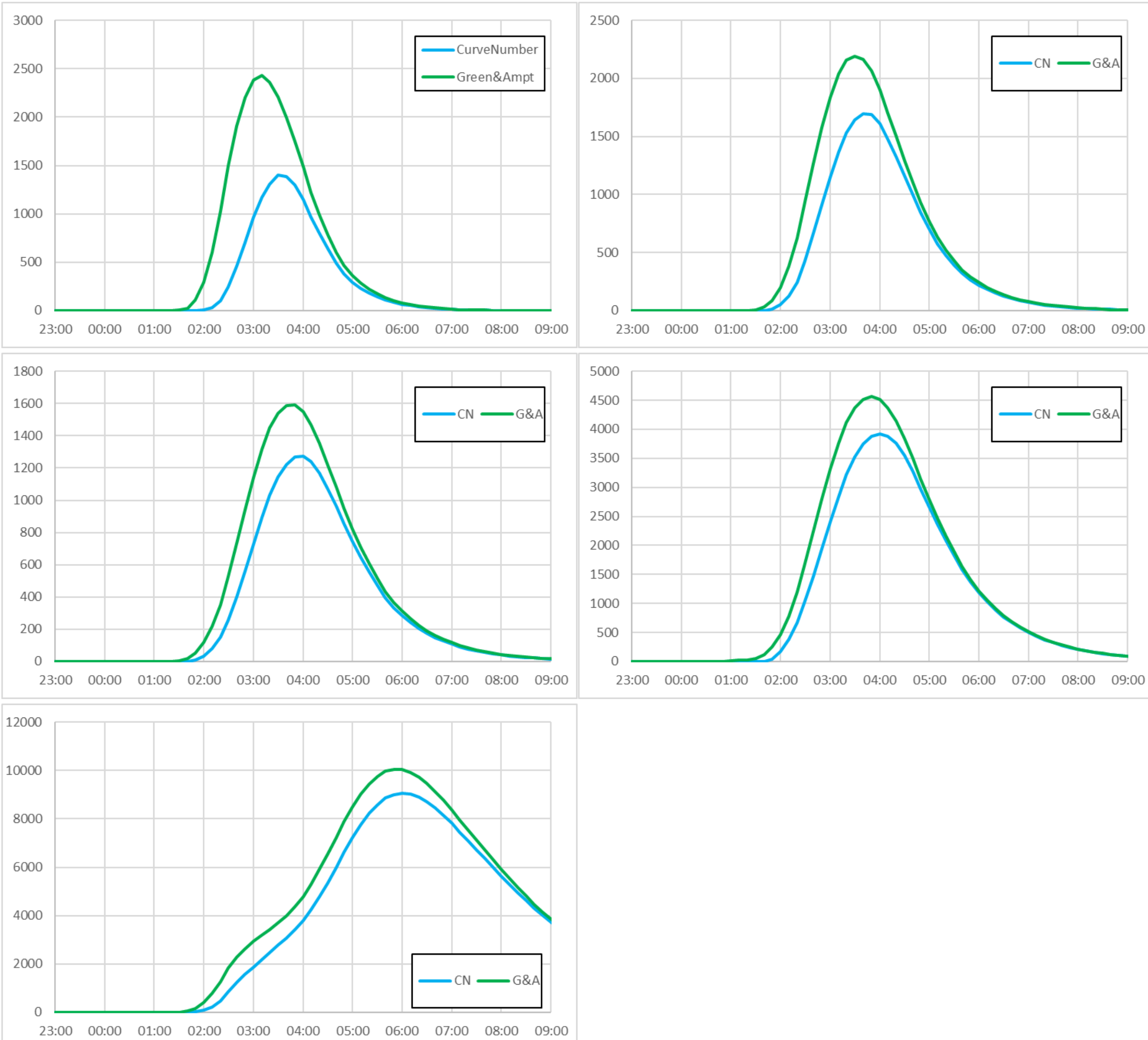

Figure 12. Modeled hydrographs for Spring Brook at River Road (top left), unnamed creek at River Road (top right), Deadly Run at DuPont Road (middle left), Armstrong Run at DuPont Road (middle right), and Hog Run at DuPont Road (bottom left). Time begins at 6PM (2300 UTC) July 12, 2021, and continues into the next day. Streamflow units are cubic feet per second (cfs). Model output shown for both the Curve Number infiltration method (blue) and the Green & Ampt infiltration method (green).

National Weather Service Hazard Products

National Weather Service forecasters typically use a combination of products to assess flash flood potential, including radar reflectivity, rainfall rates, accumulated rainfall to gridded flash flood guidance (GFFG), accumulated rainfall compared to depth duration frequency (DDF/ARI) information, and modeled unit streamflow from the FLASH project. Four (4) of these indicators make up a standard 4-panel procedure to assist with warnings – 1-hr rainfall rates, accumulated rainfall compared to GFFG, accumulated rainfall compared to DDF/ARI, and modeled unit streamflow. Archived data from these products was collected and reviewed. When two (2) of the four (4) panels show the same level of flood impact, a flood hazard product should be considered; when all four (4) panels show the same level of flood impact, a flood hazard product is strongly recommended. The output from these MRMS and FLASH products are guidance only and their usefulness may vary from event to event. NWS forecasters make a professional judgement in realtime as to the usefulness of these products, including comparison of radar-estimated rainfall to gauge observed rainfall, when available. The first hints of the need for a Flood Advisory for the impacted area were indicated by these products at about 6:50 PM (2550 UTC), with a strong recommendation by 7:20 PM (0020 UTC). A Flash Flood Warning was hinted at by about 7:10 PM (0010 UTC) with a strong recommendation by 8:00 PM (0100 UTC). A considerable impact Flash Flood Warning was hinted at by about 8:30 PM (0130 UTC) and strongly recommended by 8:50 PM (0150 UTC). An example of output from the 4-panel procedure near the peak depicted severity is illustrated by Figure 13.

The National Weather Service issued numerous hazard products during this event. The first product issued was a Flood Advisory at 8:14 PM July 12 (0114 UTC July 13), 2021. This was followed by a Flash Flood Warning at 8:42 PM (0142 UTC) and a Flash Flood Warning with considerable damage tag at 9:07 PM (0307 UTC). Anecdotal information from the post-event survey indicated that water may have begun overtopping a roadway just southwest of Seneca by about 8:47 PM (0147 UTC). The most significant impact with a known time was the washout of River Road from an unnamed creek just south of Seneca; media reports indicate that the 911 call was received for this washout at 10:55 PM (0355 UTC). Based upon the limited available information about time of impacts and output from the hydrologic model, it seems likely that NWS products provided lead time of flood impacts and significant flood impacts (Figure 14). This includes over 45 minutes of lead time between the Flash Flood Warning with considerable damage indicated, triggering phone wireless emergency alerts, and the washout on River Road south of Seneca. The earliest modeled crest was Spring Brook at River Road which occurred at 10:25 PM (0325 UTC; estimated uncertainty +/-15 minutes), which occurred more than 15 minutes after the warning upgrade. It should be noted, however, that water level crests in the headwaters of these streams likely occurred earlier. It’s possible that lead time could have been increased if hazards were issued closer to the time recommended by the MRMS/FLASH products.

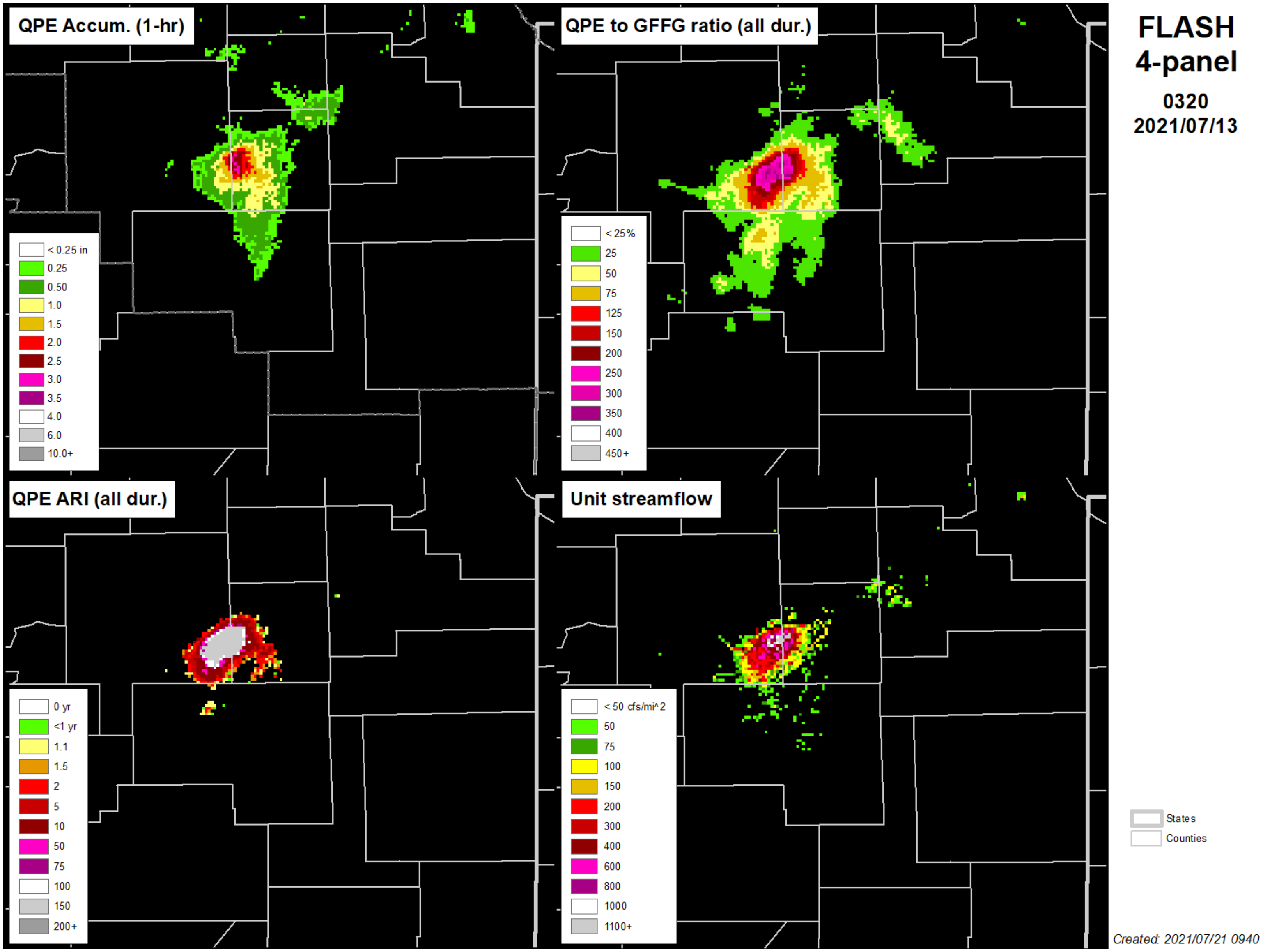

Figure 13. Values depicted by various MRMS and FLASH products near their peak during the event at approximately 10:20 PM July 12 (0320 UTC July 13).

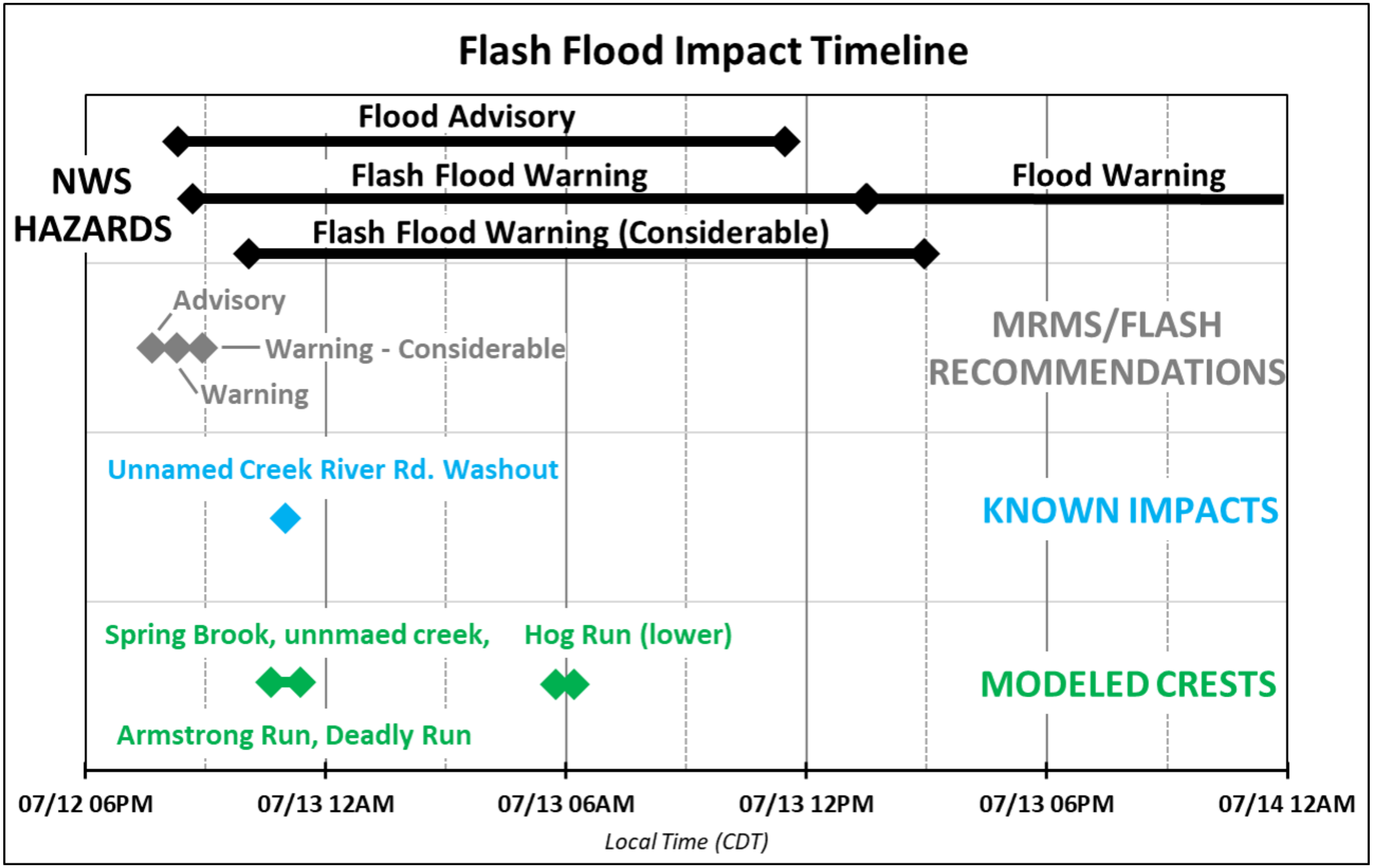

Figure 14. Timeline of NWS hazard products, MRMS/FLASH output, known impacts, and modeled crests for the event.

Conclusions

Very heavy rainfall occurred in the vicinity of Seneca, Illinois, late in the evening on July 12, 2021. Gridded rainfall estimates and rain gauges indicated that areas of La Salle and Grundy Counties received heavy rainfall, with an isolated area Seneca receiving 7.0-7.5 inches of rainfall over a 4-hr period ending at 11:00 PM July 12 (0400 UTC July 13). The amount of rainfall observed was extreme in some isolated areas, with AEP values of approximately 0.2% analyzed near the La Salle and Grundy County boundary. The most extreme rainfall impacted the Spring Brook, Armstrong Run, Deadly Run, Hog Run, and another unnamed creek, causing significant flash flood impacts. Times of modeled streamflow crests ranged from 10:25 PM July 12 to 12:55 AM July 13 (0325 UTC to 0555 UTC July 13), with limited anecdotal information suggesting impacts between 8:47 PM and 10:55 PM (0147 UTC to 0355 UTC). It is likely that the National Weather Service provided lead time with flood hazards issued for these impacts, especially for the significant flood impacts. Assuming that output from the MRMS/FLASH products were an accurate depiction of flood impacts, it is possible that additional lead time could have been achieved by issuing hazards at the times recommended by the products.