1B.4 **THE HISTORIC FLASH FLOOD EVENT OF 18-19 AUGUST 2007 IN THE UPPER MISSISSIPPI RIVER VALLEY: IMPACTS OF TERRAIN AND SOCIETAL RESPONSE**

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1. INTRODUCTION

A flash flood event of historic proportions took place in the Upper Mississippi River Valley during the night of 18-19 August 2007, with the National Weather Service (NWS), La Crosse, Wisconsin (WFO ARX), forecast area experiencing both record 24-h rainfall amounts and a terrain-changing flash flood. A backbuilding mesoscale convective complex (MCS) north of an unseasonably strong baroclinic zone, preceded by a stratiform rain event, led to the flash flood. Seven fatalities and tremendous damage to infrastructure resulted.

The Minnesota state record for 24-h rainfall (previously 275.3 mm in Fort Ripley, MN, 1972) was shattered by an official NWS Cooperative Observer measurement in Hokah, MN, of 383.5 mm. Several other unofficial 24-h measurements over 432 mm were reported in the vicinity of the Hokah measurement. The heavy rain band (>152 mm) stretched across much of southern Minnesota into southwest Wisconsin and directly affected the population centers of Rochester, MN, and La Crosse, WI (Fig. 1).

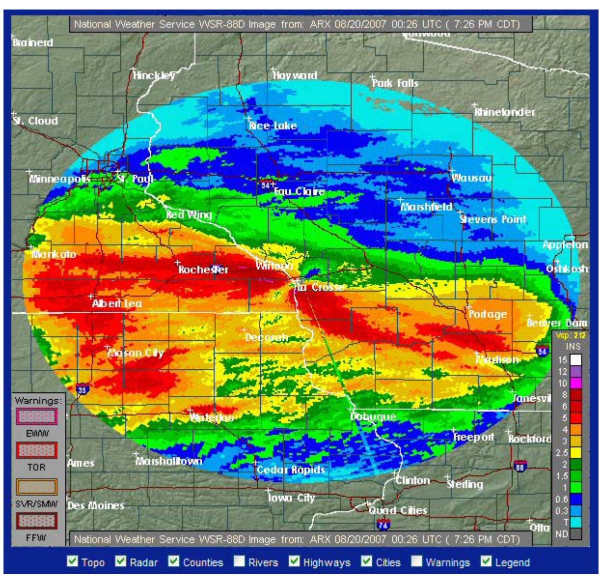

Fig. 1. KARX WSR-88D Storm Total Precipitation image following the 18-19 August 2007 flash flood event. Red hues indicate radar estimates in excess of 152 mm.

Based solely on areal coverage and amounts of rainfall, the Minnesota State Climatology Office (Minnesota Climatology Working Group, 2007) called this event one of the most significant flash floods in Minnesota state history, and roughly estimated the return period of the Hokah, MN, measurement at over 2000 years (Minnesota Climatology Working Group, 2007).

While many aspects of this extreme event are noteworthy, societal response and terrain influence were well documented in the days following the flood, and of particular interest to the author. This research will focus on the impacts of terrain, particularly the steeply sloped, unglaciated areas in the WFO ARX forecast area, and its role initiating flash flooding in rapid-response rivers throughout the area, as well as with mudslides which closed numerous roads and swept many homes down the steep bluffs. In addition, victim accounts relating to societal response of the well-forecasted event raise important questions for the meteorological community on how to communicate threats effectively that differentiate when a flash flood event of epic proportions is occurring, versus a flash flood event of much smaller magnitude.

2. METEOROLOGICAL REVIEW AND RAINFALL

During the early morning hours of Saturday, 18 August 2007, a strong northward return of deep moisture downstream of a weak middle-tropospheric short-wave trough interacted with a modest low-level jet maximum and warm frontal zone over the Central Plains. This strong thermodynamic forcing initiated a broad, stratiform rain shield with embedded convection over Iowa, South Dakota and Minnesota (Fig. 2). This area of moderate and occasionally heavy rain moved over much of the WFO ARX forecast area during the morning and afternoon hours, with widespread rainfall amounts from 25 to 75 mm.

As the back edge of this stratiform rain region approached the WFO ARX forecast area late in the afternoon (2100 UTC), warm and moist advection increased once again over the baroclinic zone, which had been reinforced via diabatic heating in the warm sector (southern Iowa) and persistent rain to the north. An elongated, intense convective rain band blossomed over the WFO ARX area through the evening and into the early morning hours of 19 August 2007, with backbuilding to near the South Dakota and Minnesota border (Fig. 3). Persistent frontogenetic forcing in the right entrance region of a seasonably strong upper-tropospheric jet streak augmented the direct thermal circulation between the upper and lower-level jets to

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focus a narrow, intense band of deep vertical motion north of the baroclinic zone. The resulting backbuilding MCS into the strong southwesterly low level jet was a classic heavy rain scenario described by Maddox et al. (1979) as a “frontal” flash flood producing MCS.

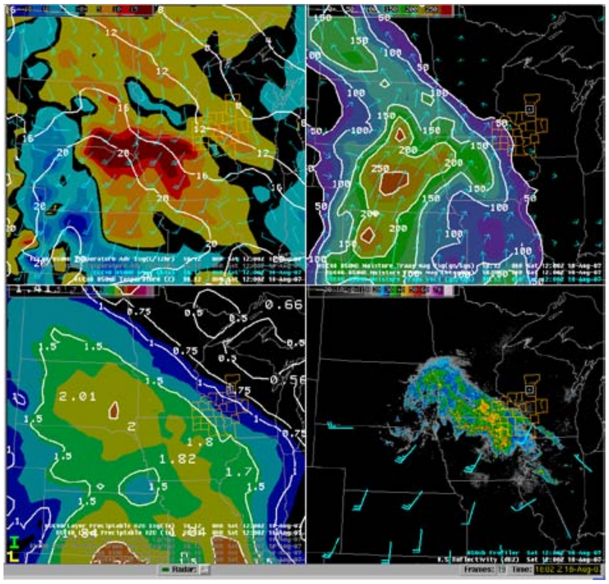

Fig. 2. AWIPS 4-panel image of 18 August 2007 stratiform rain event and thermodynamic forcing parameters. 1200 UTC RUC 0-hour analysis of 850 mb warm advection (°C/12hr, red hues, top left), moisture transport magnitude and vectors (kts g kg^{-1}, top right), precipitable water (in, bottom left), 1200 UTC WSR-88D 0.5 degree radar reflectivity mosaic with 850 mb profiler wind barbs (dBz, bottom right).

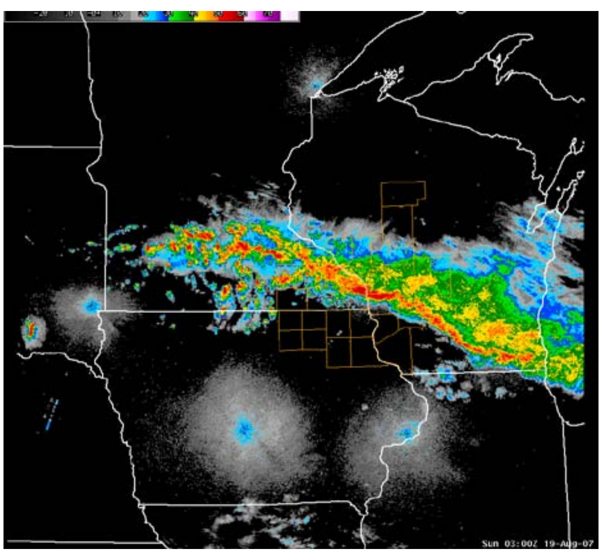

Fig. 3. 0300 UTC 19 August 2007 regional WSR-88D 0.5 degree radar reflectivity mosaic shows the backbuilding MCS in a maturing stage with intense convective radar echo building into the rain band over south-central and southeast MN.

Repeated training of convective elements began at 2200 UTC on 18 August 2007 and continued through 0900 UTC on 19 August 2007 with only a very slow southerly drift to the convective rain band through this time. In addition to a long duration heavy rain event, the thunderstorms were efficient rainfall producers. Warm cloud depths (WCD) per 0300 UTC 19 August RUC analysis ranged from 3.5 km to 4.2 km along the convective axis, suggesting warm rain processes were dominant. Cross sections of the KARX WSR-88D reflectivity data confirmed low-centroid thunderstorms, with the bulk of the thunderstorm mass (>50dBz echo) residing below the freezing level (Fig. 4).

The combination of the warm rain processes and long duration led to an axis of excessive rainfall totals from the Rochester, MN (southeast MN) area, through La Crosse, WI, into adjacent areas of southwest WI. KARX WSR-88D Storm Total Precipitation clearly showed a large region of heavy rainfall totals in excess of 150 mm along this axis, with localized maximum in excess of 225 mm. Within this rain band, a new 24-h rainfall record for the state of Minnesota was confirmed near Hokah, MN, in excess of 432 mm.

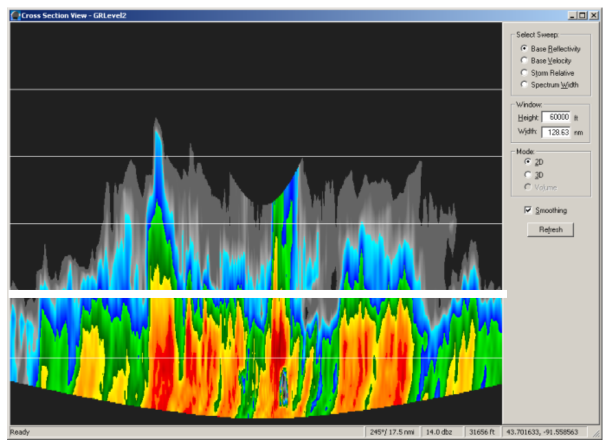

Fig. 4. 0300 UTC 19 August 2007 GRLevel2 KARX WSR-88D reflectivity cross section along convective axis in Fig. 3. Bold white line denotes freezing level. Note low-centroid storms below the freezing level indicative of warm rain processes. Thin, horizontal white lines are shown every 3.05 km. Red hues indicate radar echoes > 50 dBz.

3. TERRAIN IMPACT AND INFLUENCE

The flash flood event of 18-19 August 2007 under normal circumstances, with flat terrain, would have caused a great amount of damage and perhaps fatalities given the extreme rainfall rates and storm total amounts. Much of southeast Minnesota and southwest Wisconsin is unglaciated, and is characterized by rolling terrain. The greater proportion of waterways are small rivers and streams nestled deep within “coulees”, or narrow valleys, often with relief in excess of 200 m from neighboring ridge tops. The streams and rivers winding their way from the higher terrain into the Mississippi River respond very quickly to heavy rainfall, and cross many roads, and through many small towns along the way. This presents a unique danger of flash flooding for a Midwest terrain regime, with flash flood and river response resembling that of the Intermountain West.

Another aspect of the unglaciated region of the WFO ARX forecast area is the soil composition on the numerous steep slopes and river bluffs flanking the rivers, streams, and coulees. Often called a "driftless region" for a lack of material left behind after glacier departure, this area is not covered by deep layers of glacial till. Therefore, soils are thin and less able to retain water; they lie atop porous rock into and through which surface waters can rapidly drain into the water table (Ojakangas, 1982). Not only does this lead to rapid runoff and subsequent flash flooding of the small rivers and streams, but it may also lead to an increased number of mudslides as the relatively thin layer of soil on steeper slopes can more easily slip off the porous rock underneath. In addition to the streams and rivers which washed out bridges and roads as well as flooded towns, mudslides swept a number of homes off their foundations and down the bluff side during the 18-19 August 2009 flash flood event.

3.1 Flash Flood in Rushford, Minnesota

An example of the high-end nature of this event played out in Rushford, MN during the evening and overnight of 18-19 August 2007. A city prone to flooding, Rushford is situated just north of the confluence of the smaller Rush Creek and the larger Root River in southern Winona County, MN. Rush Creek takes in water from several smaller tributaries as it winds out of higher terrain near Interstate 90 north of Rushford seen in the accompanying map (Fig. 5).

Because of previous flooding in Rushford where Rush Creek joins the Root River, a levee system was constructed through the city along Rush Creek, but it mainly focuses on the south side of the city to protect against flooding from the Root River. Rain gauge reports in Rushford during this flash flood event show that nearly 70 mm of rain had already fallen by the time convection erupted on the backside of the stratiform rain region discussed previously. Further gauge reports show that another 55 mm rain fell in one hour during the evening hours, with subsequent rainfall the rest of the night leading to a storm total approaching 200 mm.

The overall amount of rain, and the periodic extreme rates over 50 mm/h, overwhelmed both Rush Creek and the Root River, sending them into flood. However, in this case, so much water was moving down Rush Creek into an already swollen Root River (Fig. 6) that water backed up and breached the levees on the north side of Rushford, with water then filling the entire city behind the levee structure. Pumps were needed to move water out of the flooded city back into the flooded waterways.

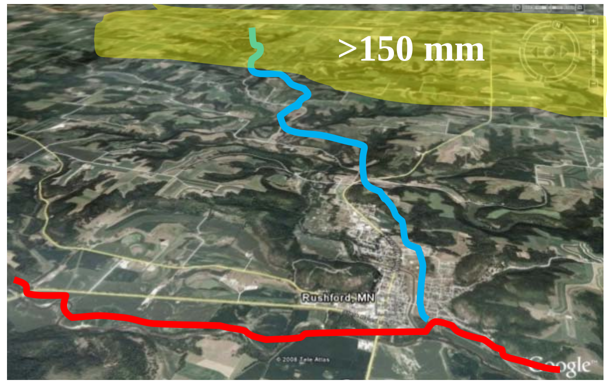

Fig. 5. Google Earth map of Rushford, MN and location of heavy rain band (yellow), Rush Creek (blue line) and Root River (red line). North is toward the top of the page.

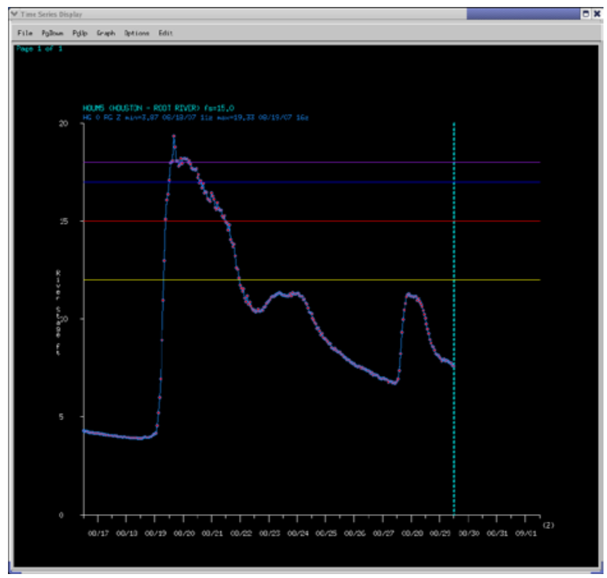

Fig. 6. Hydrograph of Root River at Houston, MN from 17-29 August 2007 showing record crest of 18.8 ft. Top horizontal line denotes previous record crest of 18.3 ft.

4. SOCIETAL RESPONSE

Follow-up surveys conducted in the wake of the flash flood event revealed some interesting aspects of how the public received, and reacted to the flash flood warnings and reports during the event.

Heavy rain and the potential for flash flooding had been forecast by WFO ARX for several days in advance of the event, and a Flash Flood Watch was issued early in the morning on 18 August 2007. The potential for flooding was well-covered by local media in the preceding days. Flash Flood Warnings in most instances were issued with ample lead-time, sometimes in excess of 60 minutes. The follow-up surveys indicated that during the first half of the event on the evening of 18 August 2007, most of the public was aware of the Flash Flood Warnings that were in effect, but few changed their normal routine or plans. Most of the individuals surveyed went to bed Saturday evening with little to no concern despite Flash Flood Warnings in effect and constant heavy rain falling.

As flash flooding worsened overnight and mudslides became more common, many were awakened during the night by the roar of heavy rain, thunder, or sirens of passing vehicles performing rescues. Those that ventured out to investigate were in many instances turned back by fire departments blocking inundated or washed out roads. Some woke to find themselves surrounded by high water and needing rescue. Still others heard outdoor civil emergency sirens and still took no action. Nearly all of the individuals surveyed indicated they will take future Flash Flood Warnings more seriously, and develop a plan of action before flood waters hit.

4.1 Flash Flood at Money Creek, Minnesota

One instance of peculiar public response to the Flash Flood Warnings occurred at the Money Creek Haven Campground, along the banks of Money Creek, during the evening of 18 August 2007. A large motorcycling club had stopped to overnight in the campground, with approximately 350 cyclists in camp when the heaviest rains began. When Flash Flood Warnings were issued for the Money Creek area, law enforcement arrived at 0200 UTC on August 19th to alert the cyclists to evacuate the campground. Some obeyed the order, but some refused and chose not to leave.

Later in the night around 0700 UTC, with still about 200 bikers in camp, a 2 m wall of water cascaded down Money Creek through the campground taking most of the remaining cyclists by surprise while they slept. Many of the cyclists had to be rescued by law enforcement, with the entire fleet of motorcycles and recreational vehicles completely ruined (Simmons, 2007). Some cyclists were forced to spend the night clinging to treetops, while the raging water threatened to drown the cyclists, uproot the trees to which they clung, or induce hypothermia. There were no fatalities, but a considerable risk of loss of life was faced by the rescue personnel who were asked to save the remaining members of the motorcycle party. In fact, rescue personnel capsized three separate life boats attempting to reach the stranded cyclists, sending rescuers into the raging water and requiring rescue themselves.

5. CONCLUSIONS

From an impact standpoint, in terms of the combination of fatalities, financial loss, and infrastructure damage, the flash flood event of 18-19 August 2007 arguably sits near the top of extreme weather events to affect southeast Minnesota and southwest Wisconsin.

Much work has already been done on public response not only to Flash Flood Warnings (Gruntfest, 2001), but also to warnings for other modes of severe weather (Barnes et al., 2007). The more extreme the event, the more difficult it becomes for NWS warning verbiage to accurately depict the tremendous impact to public safety these extreme events bring.

Currently, one product (in this case a Flash Flood Warning) is expected to cover events ranging from a nuisance flooding over a seldom traveled county road, to events like 18-19 August 2007 where hundreds if not thousands of citizens' lives and property were affected. This begs for further research into how the NWS can improve not only warning lead times, but the manner in which the NWS conveys information to customers and partners.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

Barnes L. R., E. Gruntfest, M. Hayden, D. Schultz, C. Benight 2007: False Alarms and Close Calls: A Conceptual Model of Warning Accuracy. *Wea. Forecasting*, **22**, 1140-1147.

Gruntfest, E., and J. Handmer, Eds., 2001: *Coping with Flash Floods.* Kluwer Academic Publishers, 322 pp.

Maddox R. A., C. F. Chappell, and L. R. Hoxit, 1979: Synoptic and meso-*α* scale aspects of flash flood events. *Bull. Amer. Meteor. Soc.*, **60**, 115–123.

Minnesota Climatology Working Group, "Flash Floods 2007", 2007, http://climate.umn.edu/doc/journal/flash_floods/ff2007.htm

Ojakangas, R. W., C.L. Matsch, 1982: *Minnesota's Geology*. University of Minnesota Press. 255 pp.

Simmons, D. (2007, August 20). "One long night spent in a tree." *La Crosse Tribune*

Weaver J. F., E. Gruntfest, and G. M. Levy, 2000: Two floods in Fort Collins, Colorado: Learning from a natural disaster. *Bull. Amer. Meteor. Soc.*, **81**, 2359–2366.